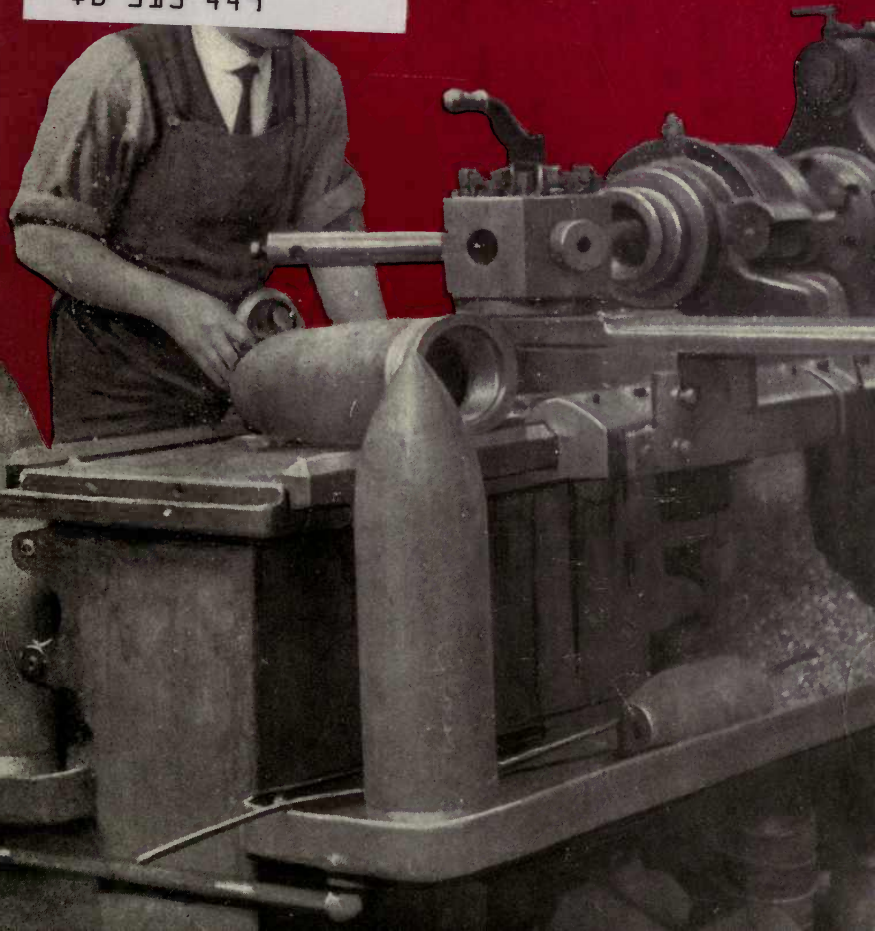
# WORKSHOP HINTS FOR MUNITION WORKERS

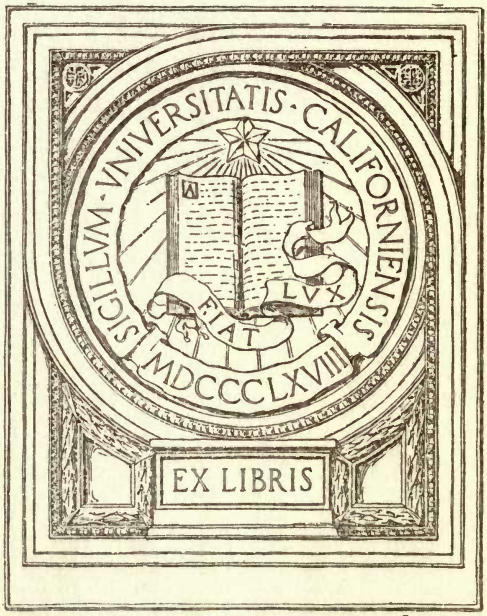
UC-NRLF
$B 315 449

Fully Illustrated



IN MEMORIAM

George Davidson 1825-1911



# WORKSHOP HINTS
## FOR
# MUNITION WORKERS

COMPILED AND EDITED BY
BERNARD E. JONES
Editor of "Work"

With about 200 Illustrations

FUNK & WAGNALLS COMPANY
354-360 FOURTH AVENUE, NEW YORK
Publishers in the United States of the publications of
Cassell & Company, Limited, London

First published *February* 1916
*Reprinted February, March and April* 1916, *June* 1917

In memoriam
George Davidson
1825 – 1911.

TJ1165
J75

# PREFACE

In this handbook is made an attempt to familiarise the reader with certain processes and tools likely to be used by him in his capacity as a munitions worker in an engineering factory. The book has been compiled largely from articles contributed to "Work" by Messrs. Fred Horner, J. R. Maidens, A. E. Riggs, and others, but it contains a proportion of both text and illustrations especially prepared for it.

To Messrs. Alfred Herbert, Ltd., of Coventry, for illustrations and for technical information on shell manufacture placed at my disposal, and to Messrs. Pollock and Macnab, Ltd., of Bredbury, Stockport, for the loan of blocks illustrating shell-turning lathes, my hearty thanks are tendered.

B. E. J.

# WORKSHOP HINTS FOR MUNITION WORKERS

MUNITION, frequently used in the plural form "munitions," is a term embracing war material of every kind except men and money. Cartridges, tents, shells, saddlery, uniforms, guns, motor-wagons, and scores and hundreds of other things—all are "munitions." At a glance, then, it will be obvious that this handbook cannot cover more than a fraction of the ground. Indeed, all that will be here attempted is to provide notes and memoranda, descriptions of certain tools, explanations of mechanical processes and operations, and other miscellaneous information designed to assist an unskilled person in arriving at some slight understanding of the materials, tools, and operations common to the work of any engineering munitions factory in which he may find employment. The desire is to make this handbook generally useful, and for that reason space is taken up with matters of interest in all engineering workshops rather than with highly specialised operations which, peculiar to certain parts of shells, bombs, cartridges, etc., have been reduced by science to a series of semi-automatic operations in which the human element plays an altogether subsidiary part. Much or nearly all of the repetition work in an engineering munitions factory is done on costly

machine tools set and adjusted by highly skilled labour to produce work of a certain size and shape, but watched and tended by labour that has only recently been imported into this particular industry But the more intelligent that unskilled labour is, the better for everybody and everything concerned; and the new-comer to the engineering workshop who has studied this handbook will master his job the sooner and take the greater pleasure in it.

**Degrees of Finish.**—There are several different ways in which metal-work may be finished, and the particular style adopted depends largely on the nature of the mechanism or part being done. There is a great deal of latitude permissible in this direction, because it is not imperative to finish some portions well; that is, the working of the mechanism is not affected. The various kinds of surface finish may be classified as follow: Black, rough-filed, smooth-filed, scraped, rough-polished, finish-polished, burnished, case-hardened, hardened, painted, lacquered, plated.

*Black finish* means that the natural skin of a casting or forging or piece of rod or bar is left untouched. This is satisfactory for some parts, including those that do not show, and is the only way in many cases, because of the difficulty of using a file or other tool on the awkward-shaped surfaces. If paint is applied subsequently there is no need to touch the metal except to give it a scrub with a wire brush; or if slight lumps are present, rub these down with a file.

*A rough-filed* surface is left after parts have been reduced to approximate dimensions and there is no neces-

sity to highly finish the faces, on account of their being concealed.

*A smooth-filed* surface is produced when the preceding mode of finishing is too coarse, either from the point of view of good appearance, or because parts cannot be fitted accurately together unless smooth-filing is done.

*Scraping* is adopted to obtain the highest degree of accuracy ; it is possible to scrape without ensuring accuracy, and as a rule it is not in good taste to scrape surfaces unless they are done so as to make good contact. The exceptions occur in some kinds of scientific instruments, where brasswork is scraped in mottled fashion, or with crossing diagonal lines to improve the appearance.

*A rough-polish* is done with emery cloth or on a revolving buff, and results in a surface more highly finished than can be done with a fine file ; but it does not have a mirror-like gloss, because the lines produced by the grains of abrasive are clearly seen in the shape of fine scratches.

*A finish-polish* is effected with the finest grade of emery cloth or on a buff, or with polishing paste used on a cloth, and if done well, following the absolute removal of file scratches with suitable grades of emery cloth equals plating in appearance, though it becomes dulled rapidly. Care must always be taken in the case of flat surfaces to control the polishing medium in such a fashion that true planes are produced ; if the surfaces are permitted to become rounding the effect looks bad. The careless rubbing off of corners which should finish keenly and sharply is also very unsightly.

*Burnishing* is performed by rubbing the surface of the

metal with a hard-steel tool, lubricated with soapy water. The pressure consolidates the surface of the metal, and gives it a highly burnished finish, which may be followed by lacquering.

*Case-hardening* gives a thin film of hardened steel to wrought-iron or mild steel, and is adopted both to enable faces to resist wear and for good appearance. Certain parts or fittings are case-hardened, often with a special mottled finish, only for pleasing appearance. Or sometimes a high polish is put on after case-hardening, only sufficient material being polished off to eliminate the surface markings which the case-hardening makes.

*Hardening* is done to tool steel, either to enable it to cut or for the purpose of resisting wear, and the hardening occurs right through the piece. The work may be polished afterwards, or the temper may be drawn, leaving a light or a dark straw colour, or a blue, which has a pleasing appearance sometimes by contrast with the other fittings.

*Painting* may be done either for appearance or as a protection against atmospheric influences in the case of iron or steel parts. It does not look well unless the surfaces are fairly smooth and free from excrescences; if such are present on a casting or forging it should be filed neatly before applying the paint. But deep file scratches must be avoided, because these mar the appearance very much, and soon cause the paint to rub off and give an untidy appearance to an otherwise well-finished job.

*Lacquering* is only required on highly polished surfaces. It affords a protective coating against atmospheric influences and enables work to retain its pristine brightness

for a long period. If the lacquer is poor or is unevenly applied, the effect is very displeasing.

*Plating* by electro-deposition offers the advantage over lacquering that there is no danger of loss of appearance through handling, heat, or friction with clothing, or anything that tends to rub off a coat of lacquer and expose the metal beneath.

**Degrees of Accuracy.**—The question of accuracy is frequently intimately related to finish, and in some portions of mechanism the mere fact of bringing the surfaces to the necessary degree of accuracy also ensures a high quality of finish. The different kinds of fits by which parts are put together range from a black fit to a scraped fit, through the intermediate range of rough and smooth filing, and from a roughly drilled or bored hole to one which is finely reamed or bored with a high degree of accuracy.

Some kinds of union are done quite satisfactorily if the cast or forged parts are merely let together as they are, with a bolt fitting easily in a cored or punched hole. Or a rough filing may suffice, this being only for the purpose of squaring up the parts to bring sections into approximate relations. A more accurate fit requires fine filing with a smooth file, and in the highest class of work the final touches have to be given with a scraper, removing minute quantities of metal from isolated spots. Some fitting can be done very well by the use of emery cloth instead of by scraping.

**Iron.**—It should be said that chemically pure iron exists only as a curiosity, and has no value as a constructive material. In combination with small proportions of carbon and other elementary bodies, as sulphur,

silicon, phosphorus, etc., it yields steel, malleable- or wrought-iron, and cast- or pig-iron. In general, the metal is called either iron or steel, the classification depending partly on chemical composition and partly on method of manufacture. The forms known as iron have been much longer in use than those known as steel, and are much easier to define. There are two familiar forms of iron, very different in their character. *Malleable- or wrought-iron.*—This is being displaced by mild steel, which, in many of its forms, it closely resembles. It is comparatively pure, containing about 99·5 per cent. of pure iron, a small quantity of carbon up to about 2 per cent., a small quantity of silicon, say ·1 per cent., and small quantities of other impurities. It is very malleable and ductile—that is, it can be rolled into sheet or drawn into wire, either hot or cold—and when heated to bright redness it becomes so soft that it can be hammered or wrought into any required form, whence its common name. *Cast-iron or pig-iron.*—This contains large quantities of various foreign constituents. The amount of iron present is usually about 92 to 93 per cent. Carbon is always present, usually about 3·5 per cent., although it may reach 4·5, and silicon may range from about ·5 per cent. (in rare cases) up to 3·5 per cent., or even higher. Cast-iron is prepared in a liquid condition, and as it flows from the furnace is usually cast into pigs, and is therefore called pig-iron. It is converted into the forms which may be required by melting and casting in moulds of sand or other material, and therefore it is often called cast-iron. This metal is useless for objects subject to bending.

**Steel.**—This is an alloy of iron and carbon, together with certain other elements present accidentally and as the merest traces, or, as in the case of "high-speed" steels, purposely introduced to form quite an appreciable percentage. A slight modification in the composition of commercial iron produces steel, which is characterised by a unique property, that of being made extremely hard by sudden cooling from a hot state. Tool steel is ordered by its "carbon content," or "temper" (always stated as a percentage). "Temper" must not be confused with the name of the process ("tempering") by which the extreme hardness of steel is reduced to adapt the tool for its particular function. The table on page 8 shows the chief tempers in which tool steel is usually manufactured—0·5 to 2 per cent. of carbon in combination with the iron. When the carbon content is below 0·5, the steel is known as "mild," and is of the kind used for structural purposes; when it ranges from 2·2 to 4·5 per cent., the material is no longer steel but cast-iron. Steel containing between $\frac{3}{4}$ per cent. and 2 per cent. of carbon is known as high-carbon steel, and is used for tools, hence the term "tool steel." The "quality" of steel means purity—freedom from phosphorus, sulphur, arsenic, etc. Phosphorus, when present up to 1 per cent., causes the cold metal to be extremely brittle—that is. "cold short"; in tool steel, not more than ·01 per cent. of phosphorus is allowable, because the higher the percentage of carbon the greater is the influence of the phosphorus. Sulphur induces "hot-shortness," there being a tendency for cracks and minute flaws to form, but it has but little

effect upon the metal when cold. Consequently the greatest care is taken to ensure that tool steel does not

| "*Temper*" or "*Carbon content*" | | *Suitable for* | *Remarks* |
|---|---|---|---|
| *Per cent.* | *Name* | | |
| $\frac{3}{4}$ or ·75 | Die | Stamping or pressing dies, miners' drills, hammers, boiler snaps and rivets. | Easily weldable. |
| $\frac{7}{8}$ or ·875 | Sett | Hot and cold setts, chisels, minting dies, large shear blades, miners' drills, smiths' tools, sett hammers, swages, flatteners, fullers, etc. | Not difficult to weld. |
| 1 | Chisel | Cold chisels, hot setts, medium shear blades, large punches and taps, granite drills, etc. | Requires care in welding. |
| $1\frac{1}{8}$ or 1·125 | Drill | Drills, large turning tools, mill picks, milling cutters, taps, reamers, small shear blades, screwing dies, small punches | Requires special care in welding. |
| $1\frac{1}{4}$ or 1·25 | Tool or turning tool | Turning, planing and slotting tools, drills and small cutters. | Cannot be welded. |
| $1\frac{1}{2}$ or 1·50 | Razor | Razors, fine turning and planing tools, files, etc. | Requires highly skilled manipulation; overheating spoils it. |
| $1\frac{1}{2}$ to 2 | — | Wire-drawing plates. | |

contain any appreciable quantity of sulphur. Steel containing more than 0·5 per cent. is unweldable.

High-speed steel is an alloy of steel with some other

metal (tungsten or wolfram, molybdenum, chromium, or manganese), and derives its name from the fact that tools formed of it can be made to cut at a much higher speed than can those of carbon steel. Quicker cutting means a saving of time, and consequently cheaper production.

**Hammers.** — The hand hammers generally used by engineers consist of four shapes, shown by Figs. A to D. The hammer shown by Fig. H is known as a "Warrington," and is mostly used by joiners. Some of the hammers used by boilermakers for riveting are shown by E to G.

Figs. I to K illustrate ball-, straight-, and cross-paned hammers. The pane, and not the face, is generally used for riveting work other than boilers. The hammer chiefly used is the cross-paned. The straight-paned hammer is not often used for riveting, because with this the pane is practically certain to strike the rivet at an angle. Some riveting and most copper and brass work of this kind is done with the ball-paned hammer; the shape of the end causes the metal to spread evenly. Riveting with a ball-paned hammer is easier than with a flat-paned one.

If a hammer head is correctly fixed on the shaft and the tool is fairly and properly used, the wear will come exactly in the centre of the face. Striking the end of a file with a hammer is an unwise proceeding, for, as well as damaging the hammer face, pieces are apt to fly off the file and injure the workman. Another dangerous practice is striking two hammer faces together, or striking the face of an anvil forcibly with a hammer.

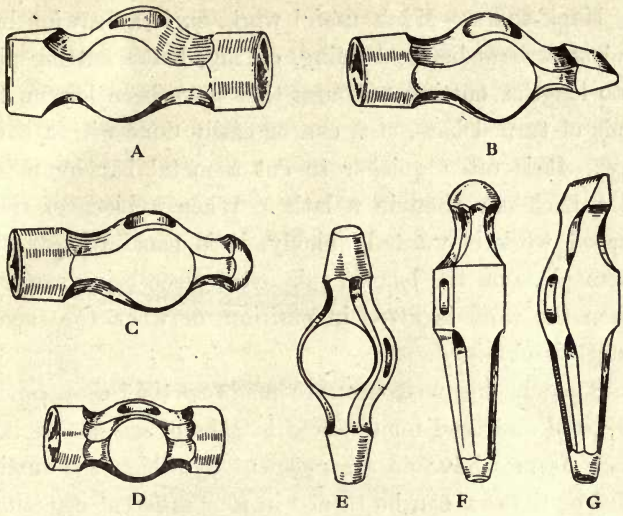
The hole in the hammer head should be perfectly

elliptical, the greater dimension of the ellipse being on a centre line passing along the length of the head. It is advisable that the hole should be slightly larger at the top end, so as to allow the shaft to expand when the wedge is driven in and prevent the head from flying off. If the hole is perfectly parallel, the head might fly off without warning, whereas with a slightly taper hole the looseness would be noticed.

The centre line of the handle should be at a right angle to both the length and width of the hammer head, and the greater dimension of the handle in line with the length of the head.

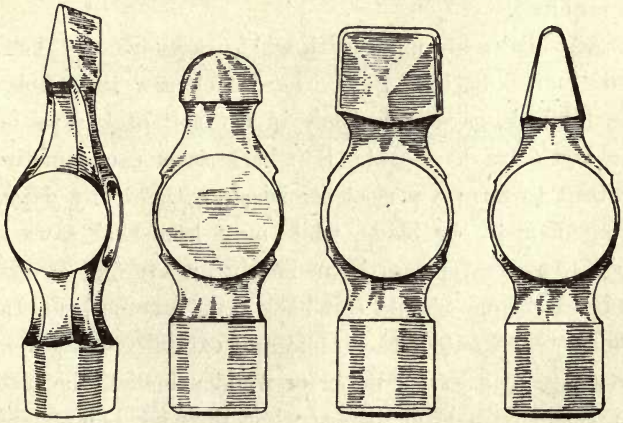
When fixing a hammer on its shaft the latter should be carefully shaped to fit the hole in the head, and a saw cut then made along the length as deep as the thickness of the head. The shaft must next be driven into the hole and a hardwood wedge driven into the saw cut. Iron wedges can be driven in with great force, but if they are allowed to get wet they soon rust and work loose.

Hammers for striking finished metalwork must be soft-faced so as not to cause marks. Wooden mallets were formerly employed for the purpose, but they are not heavy enough. A better tool is a mallet with a stout but hollow head of iron or brass, containing two boxwood blocks. Raw-hide mallets are still better, the head consisting of raw hide rolled up and compressed by machinery. But the lead hammer is regarded as the best of all, the shaft being a piece of $\frac{3}{4}$-in. steam pipe, and the head cast in place in the workshop, a special mould for the purpose being a regular article of commerce.




A to D.—Hand hammers

E to G.—Boilermakers' riveting hammers




H.—Warrington hammer

I to K.—Ball-, straight-, and cross-paned hammers

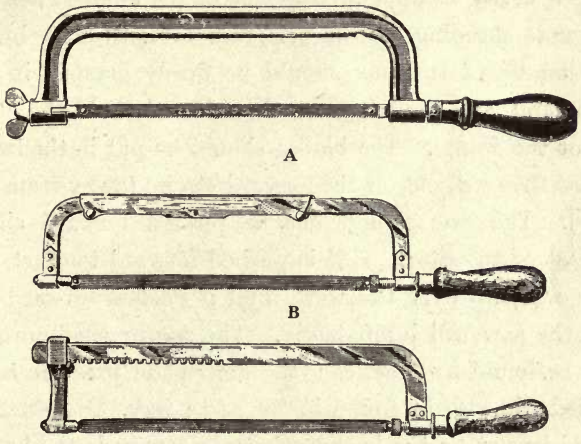
**Hack-saws.**—Much useful work, such as sawing iron and steel bars before turning, cutting bolts, cutting pipe into lengths, cutting off burrs that have been left on the ends of turned bars, etc., can be easily done with a hack-saw. It is often quicker to cut a metal bar by means of a hack-saw than in a lathe. When a piece of small turned work is wanted quickly, it is usual to leave an extra piece on the length, this extra piece being sawn off when the work is fitted in position, or when the correct length is obtained.

Some hack-saw frames are made so that they can be adjusted and used for different lengths of saw-blades, and many frames have an arrangement by which the cutting edge of the saw can be turned in four different directions, so as to cut in a downward, upward, or sidewise direction, as required.

Saw-blades are made with what are known as "hard" and "soft" backs. In the hard-back saw the whole of the blade is hardened, while in the soft-back saws only the teeth are hardened. Soft-back saws can sometimes be bent to form a perfect semicircle without any damage being done to the blade, while most hard-back saws will fly into several pieces immediately an attempt is made to bend them. Should soft-back saws become bent, they can be taken out of the frame and carefully straightened by means of a lead hammer or wooden mallet, the blades being laid on a level surface while they are being struck. Hack-saws may have either fine or coarse teeth. The usual style of teeth is about fourteen per inch, this being specially suitable for cutting soft steel, cast-iron, etc.

Slightly finer teeth will be required for hard steel, while for tool steel, iron pipe, etc., still finer teeth will be required.

"Star" blades with coarse teeth (twelve to the inch) are used chiefly for gun-metal, copper, brass, and other alloys, while blades for cutting iron and steel have finer teeth, up to, say, twenty to the inch. No lubricant is required, as it only retards their cutting properties. When



A

B

C

Three types of hack-saw frame

using the blades on iron or steel, a much slower stroke is necessary—not more than 75 to 80 per minute to obtain the best results. Any speed greatly in excess of this causes either the temper of the saw to be lowered or the teeth to be stripped. On the soft metals, 120 to 140 strokes per minute may be successfully used.

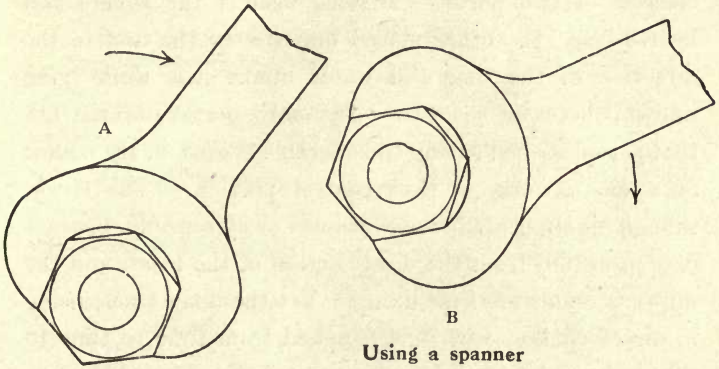
A simple cast-iron non-adjustable frame is shown at A. The blade can be turned in four directions. The

adjustable frames B and C take saws up to 12 in. long, and the blade can be turned to cut in four directions. In all the frames illustrated, the saws are simply slipped over short pegs which fit in the holes that are provided at each end. New saws can thus be quickly fitted.

When using a hack-saw, small work should be fastened in a vice at about the height of the elbow when the worker is standing upright, or from 1 in. to 3 in. lower. The handle of the saw should be firmly grasped in the right hand, and the left hand should firmly hold the other end of the frame. The blades should be put in the frame so that they will cut on the forward stroke (away from the body). The saw should not be pushed forward either too fast or too slow. If it is pushed forward too fast, the teeth will slip over the work, and if pushed forward too slow the saw will jump badly. The happy medium will soon be found by practice; the amount of pressure to be applied will also be found in the same way. No pressure should be put on the backward stroke (towards the body), and care should be taken to keep the saw-blade in a perfectly vertical position. Also, the saw should not be twisted sideways while being used; a hard blade subjected to such treatment would immediately break into pieces.

Engineering shops have power hack-saws which, once started at work, remain in operation quite untended until the metal is cut through, when the saw instantly stops. These machines save much arduous and tedious manual labour.

**Spanners.**—There is a right and a wrong way of using a spanner in tightening up a nut. A shows the correct way, and B the incorrect way, the hand in each case being assumed to be moving downwards. Used as in A the pull is such that the spanner holds well to the nut. Used as in B the pull comes so nearly in line with the nut faces that the spanner is apt to slip off the nut unless kept pressed against it during the pull. When the nut appears to be nearly tightened up, it is useless to expect that a



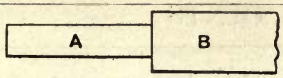

**Using a spanner**

series of jerky movements will complete the job. A steady pull must be given at the end of the spanner if a tight nut is desired. The use of a hammer on the spanner is seldom allowable. In the case of a spanner of ordinary length, the blow is ineffective owing to the elasticity of the spanner, and may possibly result in opening the jaws. Of course, if a very short spanner, say about 3 in. long, is used, a hammer blow will undoubtedly tend to tighten the nut. Spanners should fit the nuts closely.

**Forging Iron.**—Much of the work formerly done by hand at the smith's forge is now done by means of power stamps, die-presses, and steam hammers, but there are occasions on which certain hard processes come in extremely useful, and among them are drawing-down, upsetting and welding.

The formation of the smith's fire is of great importance. The "stock" is given to the mass of hard-caked coal on a smith's hearth, within which the heat is confined. It consists of two parts—one lying against the tuyère and hearth-back, the other placed opposite to the first in the direction of the coal and water bunks, the work lying midway between the two. The only portion of the fire that is replenished to any considerable degree, in the course of a day's work, is that central portion. The stock, though highly heated, does not burn away sensibly, because it is protected from the direct action of the blast, and the upper portions are kept damp. Yet the inner faces, being in direct contact with fuel supplied from time to time to the central part of the fire, are very hot. To make a fire, therefore, the stock is first built at the back and front of the hearth, and beaten hard with the slice or with the sledge, the choking of the tuyère hole being prevented by passing an iron rod temporarily into it. The fire is then lit in the central portions with a handful of shavings and a little coal, assisted by a gentle blast.

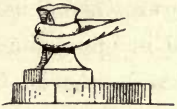
Suppose the part marked A, in Fig. A, has to be drawn down from a bar originally of the size of B. The bar is laid across the square edge of the anvil or across a block held in the anvil, in a slightly inclined direction, and nicked



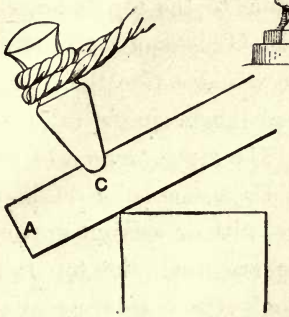

A.—Square bar drawn down

D.—Nicked bar

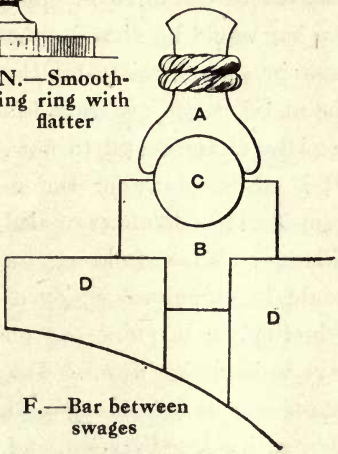
C.—Bottom fuller

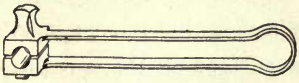


N.—Smoothing ring with flatter



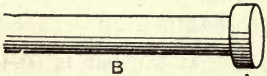

B.—Nicking with top fuller



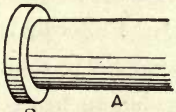



G.—Spring swages

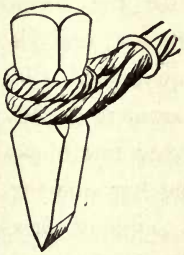
F.—Bar between swages



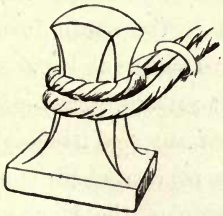

H.—Bar with collar on end



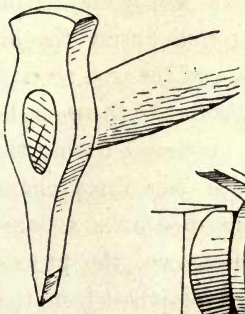

I.—Bar with shouldered end



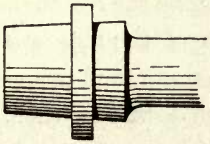
J.—Cold sett



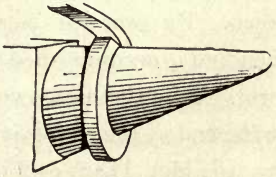
E.—Flatter



K.—Hot sett



M.—Ring on mandrel



L.—Forming ring on anvil beak

at c, Fig. B, with a top fuller. If both sides of the bar have to be drawn down, then a bottom fuller C would be inserted in the anvil in opposition to the top fuller, and the bar would be nicked as at D. Chisels or setts are not used in such nicking, for these would divide the fibre of the metal, while the round-faced fullers simply cause the particles of the metal to flow. The metal along A (A and D) is drawn down or thinned by a succession of blows from the hand hammer or sledge, with or without previous fullering. When fullering tools are used, the top fuller would be employed singly if only the one face requires reduction, or in pairs, one above the other, if both faces have to be drawn down. The effect is that a succession of depressions is formed upon the surface of the spread-out work with ridges between, and these have to be obliterated with the hammer. Fullering and hammering lengthen the bar, and also spread it sideways. If the bar is to be equal-sided, the widening has to be prevented by rapidly hammering the sides alternately with the faces. After every few blows are given on the faces, the smith turns the bar quarter round during the brief interval between a couple of blows, and the iron receives several blows upon the edges as a corrective to those on the faces, and its equal-sidedness is thus preserved during the process of drawing down. By practice, this rapid changing of the faces on the anvil is accomplished without damaging the rectangular form. In drawing down, the process of thinning starts at the end of the iron farthest from the smith, and proceeds towards him, 1½ in. or 2 in. being drawn down at a time.

A good smith can impart a fair finish to a flat surface

by the hammer alone. Striking fair with the middle of the hammer face, each mark serves to partly obliterate others, and leaves a surface that is only slightly wavy. With the assistance of a hammerman, the surface can be smoothed more effectually by means of a flatter E, which is held with the right hand of the smith, and slid in turn all over the surface of the work while the hammerman strikes it with the sledge.

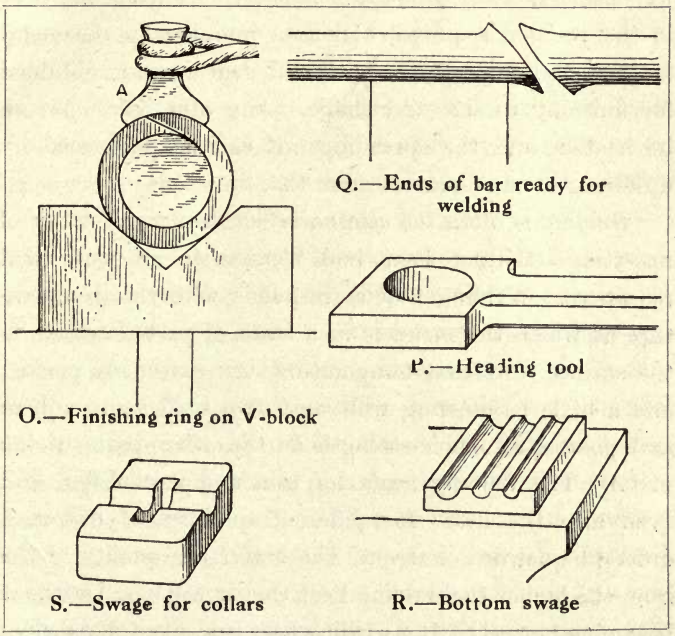
For drawing down a round bar, the rod is nicked round with a fuller and drawn down under the hammer, starting as before at the end farthest from the hand. For extending the metal, only the hammer is used, and the rod is rotated after each blow. Smoothness is imparted by means of swages, the work lying in a bottom swage of nearly semi-circular form. F shows an anvil swage fitted into the hole in the anvil, while blows are struck upon the upper surface of the rod with a hand hammer, if the smith be single-handed, or, if the smith has a striker, with the sledge upon a top swage the counterpart in form of the bottom. In F A indicates the top and B the bottom swages, with the bar of iron, C, between them; D is the anvil. By means of suitable spring swages G, a smith working single-handed can sometimes make use of the top as well as of the bottom tool. With a steam hammer this work of drawing down and finishing is very much simplified. Having marked the position of the shoulders on the bar, the smith lays the bar on the anvil of the steam hammer, and draws down the work directly between it and the tup or hammer, turning the bar quickly during each period of ascent of the tup.

While the iron is at a red heat, a scale of oxide forms

rapidly. This should be brushed off with a switch of brushwood as fast as it forms, otherwise it will be driven by the hammer blows into the surface of the work, and form a rough scale, which is afterwards both unsightly and a hindrance to easy tooling in the vice or lathe.

Upsetting, or jumping up, is one of the alternatives of drawing down, but is slower and more laborious. By this method the metal is knocked or jumped up into a mass larger in area than the bar itself. To upset a very moderate mass of metal will require several heats. Hence it is not possible to treat in this way any very large-shouldered portion ; in this case the plan is to weld on a ring or collar, or a solid mass of metal, according to circumstances. Except the iron be cut off sufficiently short to go endwise under the hammer, the use of this tool is not possible in upsetting. However, the monkey, or swinging pendulum hammer, fulfils the purpose of the hand hammer. The method of upsetting to form a collar, A (Fig. H), upon the end of a rod whose original section is that of B, and without welding the collar on as a ring, is as follows :—The end to form A is enclosed in the fire, but no more of that end is heated than the precise amount required to be upset ; that portion of the rod which joins it is kept cool and black by heaping damp coal around it. The end is brought to a welding heat, and taken from the fire. Sometimes on removal from the fire, and just before upsetting, the extreme face of the heated end is dipped into the water trough to chill it, and so the better to prepare it to resist the blows of the hammer ; but this is not always done. The actual upsetting is performed in one of several ways.

The bar may be held in both hands in a vertical position, and the white-hot end jumped down repeatedly upon the anvil face, or upon the plate of cast-iron which is often let into the ground alongside of the anvil stand for this purpose. Another way is to lay the bar in a horizontal position




upon the anvil face, holding it in one hand if light, and with a hand hammer, hammering the end to be upset. Or, if it is heavy, it may be held in both hands, or, perhaps, slung in a chain from the forge crane, and upset with a sledge hammer. When very heavy, it is laid upon the anvil face or upon a levelling block, and the swinging monkey is driven against it. When the metal for the collar is

massed in sufficient quantity, it is finished parallel in swages, and the square shoulder finished with a sett hammer or flatter, or in swages, and the end with hammer and flatter.

A collar can also be formed upon any portion of a bar situated away from the ends by localising the heat in the position required, and then jumping up the metal at that particular place, until sufficient mass is obtained for finishing to size and shape. Any other sections can be heated, and the spreading out can be performed by upsetting in one direction more than in others.

Welding is often the alternative of drawing down or of upsetting. Correct heat and cleanliness are the chief requisites. Welding heat corresponds with that temperature at which the metal is in a state of partial fusion on the surface. At that temperature it is extremely plastic, and a little hammering will cause two surfaces to adhere and possess as much strength as the other parts of the metal. The welding heats for iron and steel differ, and even also the heats for different qualities of iron and different qualities of steel. The better the quality of the iron, the higher the welding heat that it will stand without becoming burned. At a welding heat iron gives off dazzling sparks; steel shows only an intense yellow, and gives off few sparks. The ascertaining of the correct heat is a matter for experience entirely.

To illustrate the process of welding more clearly, two plain examples, one a collared rod, and the other a plain straight rod, will be described. To make the shouldered end (Fig. I), first cut off the rod, A, and then prepare to

fit over it the ring, B, for which take a square bar, say $\frac{1}{8}$ in. larger than the finished section required, and, with a hot sett (*see* J and K), cut off one end diagonally or else fuller it down. Then bend the bar roughly into circular form over the anvil horn L, and cut off to the required length, with a sloping face to lap upon and match the first diagonal. The metal must have sufficient lap to allow for welding and for dressing off and finishing. If the ring is fairly true, it will be ready to go into the fire for welding; but if not, slip it over a mandrel (M), and give the scarfed joint a neat appearance, either with the hammer alone or with a hollow tool. Then slip off the ring and flatten the faces (N). This is the plan that would be adopted in welding a separate ring. To weld it to the rod, slip the ring over the end of the rod, care being taken to remove any scale adherent to either, and then put the work into the clear fire. Sand may be sprinkled over the work, but with a really clear fire it is not necessary. When the welding heat is attained, which for wrought iron is of a dazzling whiteness, the iron appearing ready to melt, and sparks being rapidly evolved the work is removed from the fire, placed on a V-block (O), and the scarf joint and the ring are hammered all round with a hand hammer, the rod with its ring being continually turned into fresh positions on the V-block. If a hammerman's services are available, the hollow tool A is used, and a few blows upon it consolidate and smooth the surfaces. Then the faces and shoulders are finished by means of a heading tool (P), having a hole of a size suitable to take the rod, a few blows with hammer and flatter finishing off both the under shouldered face and the upper flat face.

Then it may be necessary to work over the circular part again with the hollow tool. This is to finish the surface, for the welding heat is soon past, and if the union of the joint faces is not fully effected in the first few seconds it will be more or less imperfect.

To weld a rod a scarfed joint is employed, and plenty of metal is wanted to allow for hammering the joint together and for finishing it afterwards without reducing below correct sizes ; therefore, the ends of the bar have not only to be scarfed, but to be slightly upset. The meeting ends, cut off square, are laid horizontally upon the anvil, and are upset or beaten over, while nearly at a welding heat. Then they are laid over the edge of the anvil, and scarfed or beaten down diagonally with the fullering tool, the face of the scarf being made rounding rather than hollow. Both ends having been served precisely alike they are put back into the fire, and raised to the welding heat. Lift the work vertically out from the fire ; do not drag it through the coal. Any particles of dirt that are present will show as dark specks on the white-hot iron, and should be brushed off with a switch of brushwood. The smith and his helper lay the scarfed ends together, as shown at Q, and then two or three blows with the hand hammer cause the ends to unite, and the rod can then be rapidly turned about on the anvil while the joint is consolidated all round with hand hammers or sledges. The top and bottom swages can be used for imparting the finish required. Bottom swages are shown by R and S. Without the first enlargement or upsetting of the rods, the process of welding and swaging would have thinned the rod at the

welded section below that of the other portions. How much to upset and how much to scarf are matters for experience.

**Determining Length of Iron for Rings.**—There are several methods of ascertaining the length of iron required for forging hoops and rings, and for ordinary workshop practice they answer fairly well. The best, and most probably the easiest, and the more accurate method in the end, is to calculate the length by means of arithmetic. The circumference or distance round any given circle is equal to its diameter multiplied by $3\frac{1}{7}$ (or, to be more accurate, 3·1416); but in calculating the length of iron required to make a hoop or ring, allowance must be made for the contraction and expansion of the metal, and the allowance for this is equal to the thickness of the metal that is being forged. For example, assuming that a ring made out of metal $\frac{1}{2}$ in. thick is to be $6\frac{1}{2}$ in. inside diameter when finished, to calculate the length of iron required would be as follows: Adding the $\frac{1}{2}$-in. thickness to the $6\frac{1}{2}$ in. diameter will give 7 in. Now 7 in. $\times$ $3\frac{1}{7}$ = 22 + $\frac{1}{2}$ in. for jumping up the ends and waste in welding, gives $22\frac{1}{2}$ in. total length of iron required for forging a ring of the aforesaid dimensions. This rule applies to rings that are made of round and square iron, also to rectangular iron when bent flatwise. When making rings out of flat iron bent edgewise, the same rule is followed, but instead of adding the thickness of the iron to its diameter, the breadth or width must be added. For example, assume that a ring made out of $1\frac{1}{2}$-in. by $\frac{1}{2}$-in. flat iron, bent edgewise, is to be $19\frac{1}{2}$ in. inside diameter when finished; $1\frac{1}{2}$ in. added to the

$19\frac{1}{2}$ in. is 21 in., and 21 in. $\times$ $3\frac{1}{7}$ = 66 in., the length of the iron required. Of course, the usual amount of stuff must be added to this length to allow for jumping up and allowance for waste in welding.

With regard to the amount of stuff to be allowed for jumping up and for waste in welding, the rule is (with one or two exceptions) to allow just the thickness of the iron that is being used, the exceptions being when the metal used is very thin or very thick. When very thin, a little more than the thickness must be allowed, and when very thick, a little less. No hard and fast rule can be laid down for this matter, as much depends on the manner in which the smith gets his welding heats, and the knowledge must come from actual practice and experience.

It will be seen from the foregoing, that when calculating for hoops or rings the rule is to imagine that there is a line running through the centre of the stock being used, and if the measurements are taken from this imaginary line and multiplied by $3\frac{1}{7}$, this will give the length of stuff required (allowances to be added).

But when making rings out of angle-iron, the rule or method is somewhat different. This again depends on whether the ring is made with the flange inwards or outwards, and also the strength of iron that is being used. When calculating the length of iron required for angle rings, the rule is as follows : When the ring is made with the flange outside, add to its inside diameter twice the extreme thickness of the iron at the root ; but for a ring with the flange inside, subtract twice the thickness of the iron at the root, then multiply by $3\frac{1}{7}$, as in former cases. Another

rule for making angle-iron rings is as follows : To the inside diameter of the ring being made, add two-thirds of the width of the bottom flange, and multiply the total by $3\frac{1}{7}$. For example : assume that a ring made of $1\frac{1}{2}$-in. angle-iron has to be 13 in. inside diameter when finished. By adding 1 in. (the $\frac{2}{3}$ of $1\frac{1}{2}$) to 13 in. = 14 in. ; this multiplied by $3\frac{1}{7}$ = 44 in., which would be the length of angle-iron required for making the ring of the dimensions given. Of course, the usual amount allowed for waste in welding must be added.

**Forging Tool-steel.** — When cutting off pieces of tool-steel from the bar prior to forging, it is necessary first to nick round with a cold chisel, and then smartly strike the bar near the nick, the end to be cut off being unsupported. Some mechanics strike the bar on the edge of the anvil, the shock causing the short end to drop off. In larger sizes—say, from 1 in. to $1\frac{1}{4}$ in. thick—it is inadvisable to break off cold, the best method being to heat to a bright red and cut off by means of a hot sett, before the material gets chilled. If desired, the piece can be nicked round while hot and broken off while cold ; but in order to guard against the development of cracks during hardening, it is often advisable to cut off hot. There is little risk in breaking annealed bars while cold, as the process of annealing tends to relieve any strains that may exist. The breaking of large unannealed bars while cold sometimes sets up internal stresses, which cause cracks when the steel is being hardened. For forging, the material should be slowly and evenly heated in a clean fire or special furnace, it being useless to attempt

to heat the steel in a half-burnt-out fire. Small coke gives excellent results, but some smiths use a mixture of coal and coke. The temperature given in the table below should not be exceeded. Overheating burns the steel, and is evidenced by the formation of scales and an appearance of pitting. In the case of slight surface burning, a thorough hammering at the right working heat will effect an improvement. Bring the heat up gradually, so that the steel is of one uniform temperature throughout, before beginning to hammer out. Do not give light blows; the blows must practically squeeze the metal to

TEMPERATURE FOR FORGING CARBON STEEL

| *Temper of steel* | | *Maximum temperature* | | |
|---|---|---|---|---|
| *Name* | *Carbon content* | *Degrees, F.* | *Degrees, C.* | *Maximum colour* |
| Razor .. | 1½ | 1,472 | 800 | Cherry red. |
| Tool .. | 1¼ | 1,517 | 825 | Bright cherry red. |
| Spindle | 1⅛ | 1,562 | 850 | Red. |
| Chisel .. | 1 | 1,607 | 875 | Full red. |
| Sett .. | ⅞ | 1,652 | 900 | Bright red. |
| Die .. | ¾ | 1,742 | 950 | Full bright red. |

shape. Cease hammering after the steel has got below a dull red heat, unless the drawing out is finished and the hammering is required for stiffening purposes. A metallic sound when hammering is evidence that the steel is not hot enough.

Should the hot steel touch a cold or wet surface, a sudden and local contraction will be caused, and this will give rise to surface cracks. For this reason see that the

gripping tongs are heated to a black red before they are used for holding a heated piece of steel. Another precaution is that the hot steel should not be placed directly in a cold draught or blast of air.

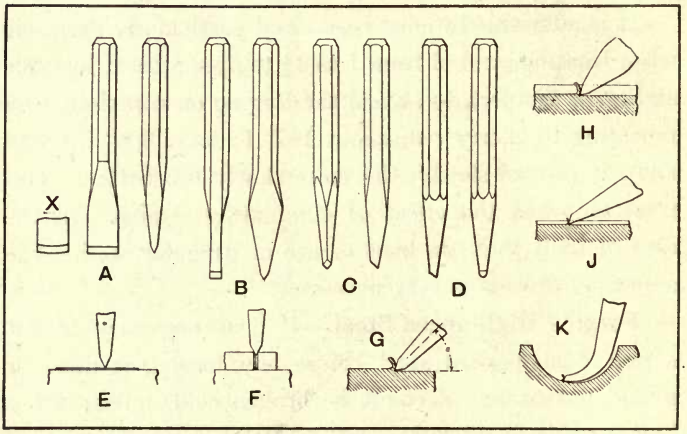
Precautions in drop-forging tool steel are to see that the heat is kept well up, and that too much work is not attempted in one operation, it being borne in mind that tool steel does not flow so quickly as mild steel.

It is advisable in most cases, and particularly desirable when treating steel of from 1 to 1½ temper (chisel, tool, file and razor temper), to anneal the forging on completion by reheating to cherry red, about 147° F. (say, 800° C.), and allow it to cool slowly, the more slowly the better. This treatment has the effect of eliminating strains. In the case of tools that are bent or are of irregular section the annealing process is very necessary.

**Forging High-speed Steel.**—If it is necessary to cut a bar of high-speed steel before any forging is done, it should not on any account be broken cold, unless it has been previously nicked round. If this precaution is not observed, small cracks may be started at the end of the bar, and these might develop further when it is hardened. It is best to cut the bar through at a forging heat. Before forging, the steel bar should be thoroughly heated to a very bright red, verging into yellow heat, which is about 1,850° F. (1,010° C.). The bar at this temperature somewhat resembles the glowing fibre of an incandescent electric lamp, and in this state it can easily be forged. Hammering should not be continued after the temperature has so lowered that the bar is of a medium red colour

(about 1,400° F. or 760° C.), when forging should cease and the steel be reheated. On no account should the steel be struck if a metallic sound is noticed while hammering.

**Chisels and Chipping.**—Chipping is an important operation, especially in shops unprovided with machinery. Castings and heavy forgings are readily prepared with the




**Various chipping chisels and their use**

chisel to be worked on with files and finer edge tools. The chief four kinds are shown in A to D. E shows the use of a chisel in the simplest manner for cutting sheet-metal laid on a block, and F the nicking of a bar all round, preparatory to snapping it off. Ordinary chipping of a surface is shown by G, while H and J illustrate the chipping of grooves with a cross-cut and a round-nose or a diamond-point respectively. For cutting grooves in bearings, the oil-groove chisel (a bent round-nose) is applied as in K.

The harder the metal the more obtuse must be the angle of the cutting edge of the chisel, otherwise the keenness of the edge will be lost rapidly. Thus an angle as keen as 30° will suit for copper and brass, while one as obtuse as 65° will be necessary for hard steel. An average angle of 45° to 50° is suitable for the general run of work in cast-iron, wrought-iron, and mild-steel. It is better to grind the edge of a flat chisel with a slight amount of rounding (slightly exaggerated at X, diagram A). This prevents the corners from digging into the metal and breaking, and enables one to pick out a more localised area when truing up a surface, since it is possible to use only about one-third of the width of the edge in taking a light chip. For cutting wrought-iron and copper it is an advantage to use a lubricant, either oil or water, with which the chisel edge is moistened occasionally; but for other materials lubricant is not necessary.

**Files and Filing.**—Files are obtainable in far too great variety to allow of their being all illustrated here. Diagram A (p. 33) shows nine sectional shapes, which meet most ordinary demands. They are: A, the square file, employed chiefly for filing holes and slots, or between narrow faces; B, the flat file, made in various thicknesses and applied for all kinds of flat work; C, the knife-edge, for narrow places and for cutting off instead of using a saw; D is a cotter file, used chiefly for rounding the ends of slots; E and F, triangular or "three-square" files, used for grooving, saw sharpening, and generally dealing with angular situations; G, the round file, for enlarging holes, or finishing radii at the ends of slots or forked openings,

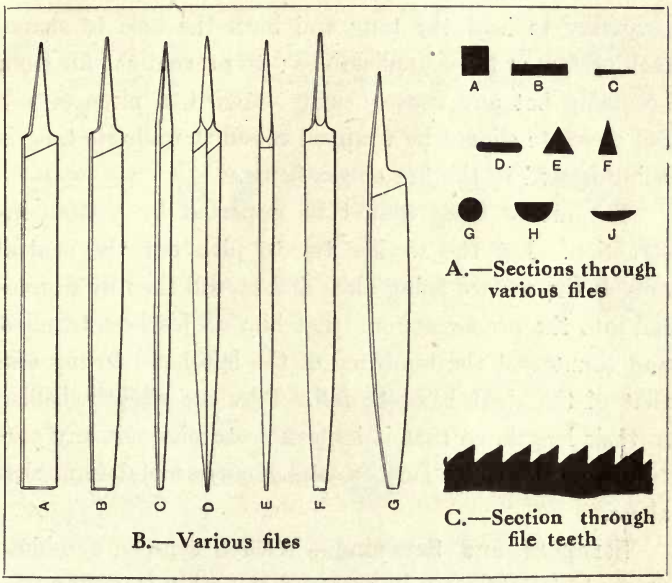
and the half-round sections H and J perform similar functions, as well as being useful for roughing out by filing a series of crossing grooves.

B represents longitudinal shapes. The flat file A is necessary when slots or shoulders have to be filed parallel. A rough file with bellied sides B is handy for some kinds of work. The square file C and the triangular file D are most convenient made as shown, with a good amount of taper, and the round file E is also most generally useful of that form. But when a series of uniform radii have to be filed (as for saw gulleting), the round file is better of parallel form in its length. The half-round F and the knife-edge G are also preferably tapered in the length, the exception being for saw gulleting, which is better done with a parallel half-round. For very fine work the needle files, with round parallel tails, are very convenient.

The shape of the file teeth is shown by C. If the backs are sandblasted after cutting with the chisel, the edges come up keen and clean; but when left as from the chisel they are not so perfect, there being a slight burr or curl pointing backwards, and this reduces the cutting power. The teeth are either single or double cut. In the first-named there is one series of teeth, lying at an angle across the file. In the second, another series of teeth crosses the other, and leaves a number of points standing up in place of the continuous cutting edges of the single cut. The latter, however, is chiefly suitable for working in soft materials, as brass, lead, pewter, and also for wood, bone, ivory, etc., while it is also employed for finishing work running in the lathe. The double cut is required for

general metalwork, including brass, gunmetal, bronze, iron, and steel.

Both the single-cut and the double-cut files are supplied in six degrees of coarseness. The cuts in the single-cut files are termed rough, middle, between bastard and middle bastard, second cut, smooth, and dead smooth. In the




A.—Sections through various files

B.—Various files

C.—Section through file teeth

double cut they are rough, middle, bastard, second cut. smooth, and dead smooth.

A safe edge on a file is one on which the teeth are absent, and may be had on the flat files; on square ones the user has to grind a safe edge if he desires it. The reason for having one smooth edge is that this may be brought up against a shoulder safely without risk of filing

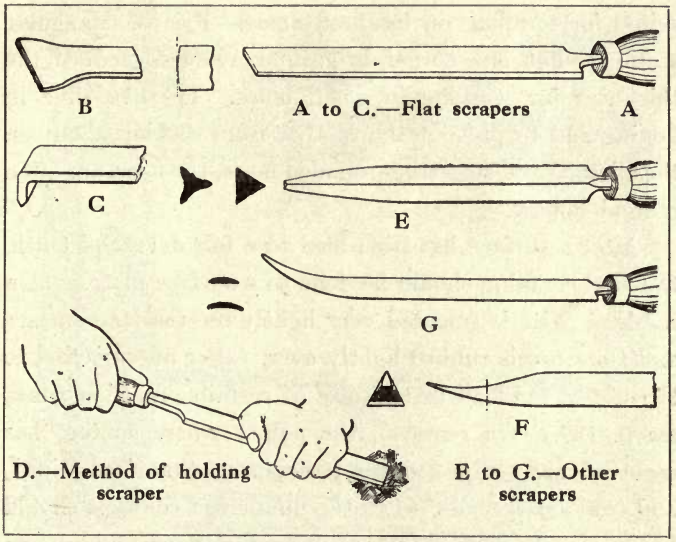
the latter away, because it is almost impossible to be sure that a fully cut file will not take off a little when its side touches a shoulder inadvertently.

The length of a file is measured minus the tang. The fitting of the latter into the handle is done by simply boring a hole and forcing in the tang, if the handle is of soft wood. If of hard wood this method is not successful, and it is necessary to heat the tang and burn the hole to shape, making two or three applications; to prevent the file from becoming hot and consequently softened, a piece of wet rag or waste should be wrapped round it while its tang is being heated in the fire or gas-flame.

The art of filing cannot be imparted by written instruction. Let the worker try to pick out the central area of the surface being filed, and he will then by degrees fall into the proper action. Let him do his best to resist and counteract the tendency of the left hand to rise and that of the right hand to fall. Files are slightly bellied in their length, so that it is possible to pick out any particular portion of a surface, and remove metal from that alone.

**Scrapers and Scraping.**—With a scraper a minute amount of metal may be removed smoothly from any portion of a flat or curved surface, it being thus possible to fit parts together mutually, and to obtain such intimate contact as to prevent the passage of steam under pressure. Any surface which needs to be very true, either for the purpose of making a joint or for producing a high-class sliding or revolving contact, is therefore scraped after machining or filing or boring. Scrapers are of two prin-

cipal kinds, for flat and concave surfaces respectively. A flat file is generally used for the former, ground square at the end (*see* diagram A), and having a very slight degree of rounding transversely, as indicated in the plan view. With a straight edge it would be difficult to pick out a particular spot on the work, because the scraper tends to



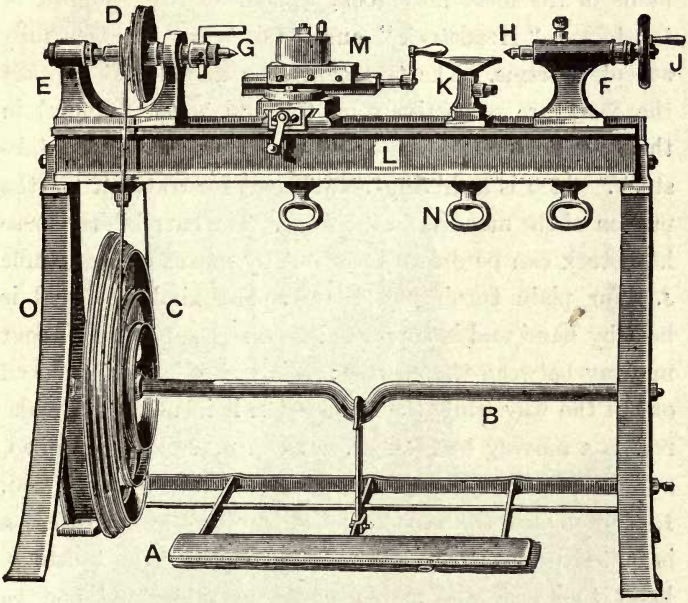

cut with its whole width. B and C are two alternative forms of the end, the former being preferable for removing a quantity of metal quickly, and the latter, the hook scraper, being held horizontally as illustrated. The ordinary flat scraper is held as in D for heavy scraping, or in a more delicate manner for light finishing, using the fingers and thumbs for grasping instead of the whole grip of the hand. The edges must be kept oil-stoned keenly,

or it will be difficult to make the tool cut without applying excessive pressure; and the stoning must be done smoothly, as otherwise the scraper will leave scratches on the work.

The scrapers for concave surfaces are made from triangular or half-round files, or from steel of those sections. The principal kinds are shown, E representing the straight type, and F and G curved forms, the latter being better suited for scraping on localised areas. F is of triangular section; but one corner is ground away to reduce the thickness for working in small holes. To save time in honing and to prevent the scraper from rocking about on the oilstone and so getting rounded faces, the faces are often ground hollow.

After a surface has been filed to a fair degree of truth, the final scraping should be done to a surface-plate. Thin red-lead paste is smeared very lightly on the trial surface and the work is rubbed lightly over. (For an objection to the use of red-lead in the case of certain munition work, *see* p. 137.) On removal, the points where contact has occurred are scraped down judiciously, the piece wiped, and trial again made, when the number of contacts should be increased. These are again scraped down, and so on until the spots where the red-lead is transferred occur fairly all over. If a high degree of precision is desired, the scraping is carried on until very intimate contact is secured, as shown by the bright spots caused by the rubbing of the pieces together, without using red-lead at all. Very great care must be observed in the later stages, or the work may have to be done all over again.

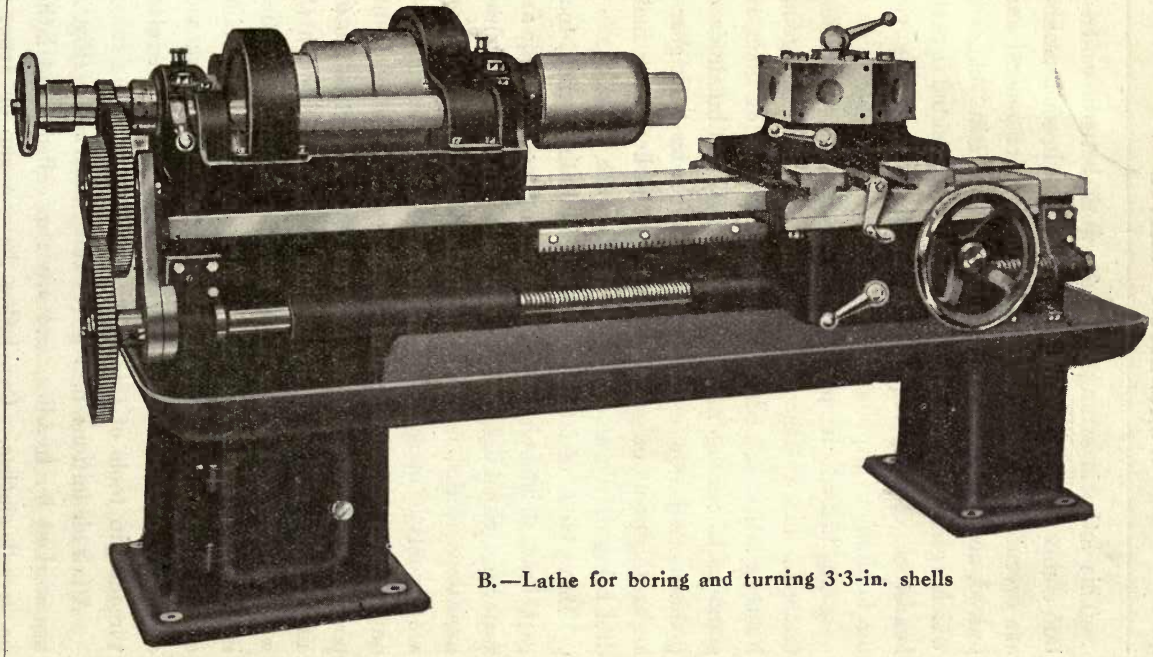
**The Lathe.**—The chief of all metal-working tools is the lathe, and the munition worker entirely fresh to the subject may be informed that the principle of turning metal in a lathe is that of rotating the work on its own axis while cutting it with a tool. The time-honoured type of lathe—a foot lathe—as used in small shops and




**A.—Simple lathe with its parts lettered**

by amateurs will first be briefly described, so that the reader may gain a general idea of the shape of the tool and the names of its parts. Illustration A shows a lathe which, without the slide-rest M, would be of the simplest type obtainable. A heavy iron stand, with tie-rods, fitted with treadle motion, supports the top, known as the

"bed," L. A is the treadle, which works crank axle B, carrying the grooved flywheel C. From this a twisted gut band drives the grooved pulley D, the whole of the casting E containing this pulley being known as the headstock. In a simple lathe there are always two headstocks or "heads," the other being shown at F and going by the name of the loose headstock, back headstock, poppet, or tailstock. "Headstock" and "tailstock" are generally accepted terms. The two centres G and H that support the work are respectively on the end of the mandrel in the headstock, and on that of the barrel in the tailstock. At G is a driving attachment for transmitting the motion of the mandrel to the work. The barrel in the loose headstock can be drawn in or out by means of the handle J. For plain turning of the simplest kind, the tool is held by hand and is supported on a rest somewhere about midway between the centres; this rest K is shown placed out of the way while the slide-rest M is in use. The slide-rest is a moving tool-holder. It can move along the bed, and, in addition, one of its slides can move across the bed. In the elementary type of lathe shown, the headstock E is bolted permanently to the lathe bed, but the tailstock, hand tool rest, and slide-rest are movable, and can be secured by the screw handles N just where they are required for use. The bed L and the side standards O must be substantial, for should the metal bend appreciably as a result of the pressure exerted by the clamping screws and bolts, the centres are thrown out of alignment, and the work produced is slightly taper instead of being parallel.



B.—Lathe for boring and turning 3·3-in. shells

This lathe is arranged to take work between centres; but comparatively few of the operations in shell-making are executed on work so held, it being more general and, indeed, absolutely necessary to hold the work in "chucks," which (generally) occupy the position indicated by the headstock centre. A chuck is simply a revolving vice for holding or gripping the work.

Few, indeed, if any, of the present-day munitions factories use a lathe quite so simple as the foregoing. Factory lathes are run by power, and some of them are giant tools costing many scores and often hundreds of pounds. All power lathes are fitted with back gear—an arrangement of gears allowing of the headstock mandrel being driven at a speed that suits the work.

Many kinds of lathes are in use, including bench, foot, gap, brass-finishers', turret or capstan, screw-cutting and surfacing, chucking, boring, etc., etc. In well-appointed munitions works, many of the lathes used for small work are automatic or semi-automatic machines, working without skilled attention, and feeding the material into position as parts are made and cut off. A vertical boring and turning mill is really a kind of lathe, although the work is operated upon while turning around a vertical instead of a horizontal axis; in many works machines of this class have taken the place of lathes for work such as heavy castings and forgings. Shell noses are often threaded in tools of this type.

A few definitions may be useful. Foot lathes (Fig. A) are worked by treadles, and are also called hand lathes or treadle lathes. Gap lathes have a gap or space in

the bed at the faceplate end, so that short work of large diameter (as a flywheel) can be turned. Brass finishers' lathes are used by brass-turners, and are fitted with a number of attachments, which are arranged to facilitate the rapid production of interchangeable parts; as a rule, they only have one spindle, are without back gear, and run at a high speed.

Turret or capstan lathes (Fig. B) are fitted with an attachment that is similar in appearance to a capstan as used on a ship, and this is fitted with a number of tools so arranged that they can rapidly be brought into use, one after the other. The turret is mounted on a slide carried on a hollow saddle, thus making possible both "sliding" and "surfacing." Such lathes will be found in most engineering munitions factories.

Sliding, surfacing, and screw-cutting lathes are the types most used by engineers. The term "sliding" indicates that the saddle of the slide-rest can be automatically traversed along the bed, and the term "surfacing" points out that the tool and cross slide can automatically be traversed at right angles to the bed. The word "screw-cutting" is used to denote that the lathe is fitted with a leading screw, and can be used for cutting threads.

Chucking lathes have been generally used for roughing-out work that had ultimately to be finished on another machine: but chucking lathes are now commonly being used for completely finishing holes.

Boring lathes are generally used for boring and other work that requires the hole to be machined and some flanges faced. Most turret lathes are boring lathes.

Wood-turners' lathes are cheaply constructed, run at a high speed, and have no back gear; they are often fitted with a large faceplate on the outside end of the lathe spindle.

Toolmakers' lathes are accurately constructed, and are fitted with a number of attachments in order to render easy the manufacture of accurate tools; lathes of this class are acknowledged to be the finest tools made, and are mostly found in departments where the delicate tools are made.

Munitions factories have evolved a number of special lathes, as, for example, the shell waving lathe, special boring lathes, etc.

The driving attachment H is most commonly used for quite small work, fitting the hollow part of the centre. The pointed centres A fit into recesses made in the ends of the work, and when in position the work is said to be "between the centres." In diagram H the driving arm B passes through the spindle, and presses against the carrier or dog that is fastened on the material that is being turned; as the lathe spindle revolves, the driving arm carries the carrier and the work along with it.

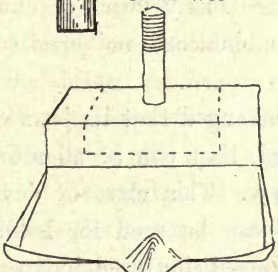
Instead of this driving attachment, a driver plate E is generally employed for work of any size. The chuck plate A is screwed on the lathe spindle, and carries the driving peg B. This touches the carrier C, which is fastened, by means of the screw D, on the spindle E held between the centres F and G.

The straight-tailed carrier F consists of a cast-iron or malleable-iron frame A, through the hole in which the

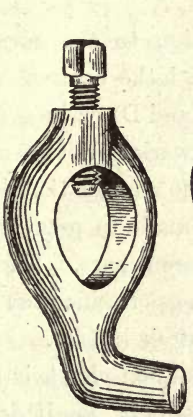
bar of iron passes and is prevented from slipping by means of the set-screw B.

The bent-tailed carrier G is made of drop-forged steel, the tail being oval to give additional strength. When a

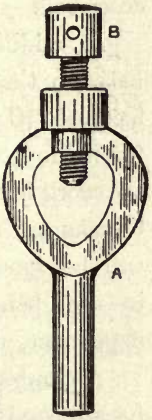
H.—Driver for small work



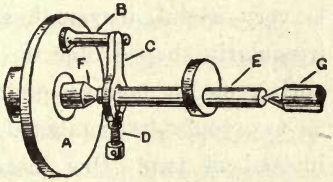
J.—Shield over central stud of tool-holder



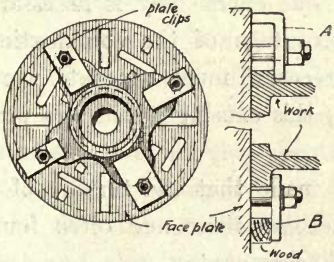
G.—Bent-tailed carrier



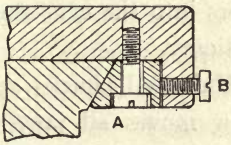

F.—Straight-tailed carrier




E.—Ordinary type of driver plate




C and D.—Work attached to faceplate with clips A and B




I.—Adjusting V-strip of slide-rest

carrier of this description is used, the driving pin B (Fig. E) is dispensed with, the tail passing through a slot in the driving plate. Double carriers are used with special faceplates having two driving pegs. Many other types of carrier are in use, but they need not here be described.

In addition to the turning of cylindrical bars held between the lathe centres, work is done while held on a faceplate (C and D) or in a chuck. The use of a faceplate for holding work is not recommended, but in many cases the work is so shaped that it cannot be held in a chuck. Chucks are made in great variety, but the smaller kinds will be ignored here. There are many forms of chuck in use, being classified as combination, universal, independent, draw-in, etc.

A combination chuck is so arranged that its jaws can be adjusted singly, or, if desired, they can be all moved an equal amount simultaneously. This class of device is very useful, inasmuch as it can be used for holding irregularly shaped objects (its jaws being used independently), or for holding perfectly circular parts. Further, as two tools are combined, one chuck only is necessary instead of two. One disadvantage of the combination chuck is its relatively high cost; much accurate work enters into the construction, this causing expense in production.

Universal chucks are so made that the turning of a screw moves all jaws, sometimes three and often four, simultaneously and each a like amount.

Independent chucks are so called because the jaws are

arranged to act independently of each other. Such chucks are useful when the work has an irregular outline.

Draw-in chucks are extremely useful appliances, which do not appear to receive the attention they deserve. Much work in the form of small screws, washers, nuts, etc., can be done with the aid of these chucks, thus dispensing with the centres. Another advantage of this type is that its use obviates waste of material, as, a carrier not being used, a spare length is not required, it being possible to work close up to the chuck. Of course, with a draw-in chuck it is necessary that the lathe spindle should be hollow. Many of the draw-in chucks are of the collet type, in which a series of rings or bushes grip the work. This type has proved particularly useful for holding large shells during the heavy operation of boring—work that could not properly be held in ordinary jaw chucks.

The slide-rest forms part of most modern engineers' lathes. It supplies a mechanical means of applying and guiding the cutting tool. The great superiority of its use over handwork is caused by the rigidity with which the tool can be held, and the true guidance of the tool in the line of the cut required. The straight line of guidance is given by the slides, which must be mechanically straight and true. Slide-rests on munitions lathes are compound, that is, they possess two slides—one that will face work held on the faceplate or in a chuck (this slide is then at right angles to the lathe mandrel), and another that will work parallel with the centre line of the mandrel and also swivel round for taper work. It should be marked on the circular flange with a zero, indicating

when the slides are at right angles to each other, and there should be degree marks on each side of the zero mark for the purpose of taper turning on short work between centres or in the chuck. A worker who has been put in charge of a new slide-rest, should first clean off any grit and accumulation of dry oil upon it with a soft rag soaked in paraffin or petrol, and should then wipe dry and apply machine oil to all parts, working the slides from end to end, and noting if the moving parts appear of the same degree of tightness in fit the complete length travel. Also, he should inspect the screws that hold the adjusting strips (*see* Fig. I, p. 43), and try with a screw-driver to see that screw A is jammed hard up; the screw B is for adjusting the strip and keeping it from easing back. It should be noted that the holes for the screws A are elongated to allow for lateral movement when adjustments are required. It is important that the sliding parts be clean and periodically examined for adjustment and always kept in working order. No slackness of fit should be permitted, as this will cause irregular work, vibration, and possible chattering of the tool, but at the same time the opposite extreme of adjusting too tightly should be avoided. After using soap-water for turning wrought-iron and steel, all chips and moisture should be wiped off, and the surfaces oiled over to prevent corrosion. The practice of fitting a tin shield over the central stud of a universal tool-holder, as shown in Fig. J, is a good one, and will save the metal chips and water from entering the slides. Sometimes a piece of American cloth is used for the same purpose. The soft-soap water

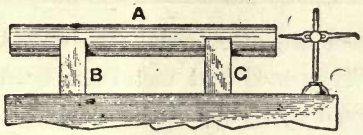
may be caught in a tray underneath, strained, and used again.

**Centring Lathe Work.** — In modern lathes the Morse taper centres are usually employed. The proper centring of the work preparatory to placing it in the lathe is very important. A bar that is reasonably true at the outset—for example, drawn bright steel rod—may be first marked out on V blocks with a scribing-block, as in A and B (p. 49). The V blocks B C are placed on a surface plate, and, with the scriber just above the actual centre, four lines are drawn on the end, the hole then being centre-punched in and afterwards drilled to form the perfect centre shown in Diagram C, the lathe centre being hardened. A rapid method of centring a bar of metal for turning is first to file the end of the bar clean and square, and then with the hermaphrodite callipers D scribing four lines. With a centre-punch E ground to a fine point, holding the bar in the vice, strike a centre-pop as nearly in the centre of the square as possible. If the punch is ground up by hand give it a turn or a part of a turn between each blow to prevent the hole taking up the imperfections of the punch. When satisfied with the depth of the hole F, a second punch with a blunter angle G may be used as at H. This requires a slighter blow—just enough to give a proper bearing of the *same* inclination as the lathe centres. Of course, a hole may be drilled up after the first centre is made, but the above method is quicker and will produce the same result—that is, it will prevent the lathe centre from bearing on the bottom of the hole.

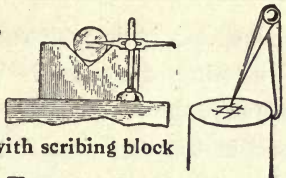
For centring small bright bars, the best method, especially if a hollow mandrel is available, is to hold the stuff in a self-centring chuck and to start the centre with a pointed hand tool, taking care to remove the pip which tends to form in the centre of the recess. A drill and afterwards a countersink may then be employed properly to form the centre. A square back centre I, or, better still, a fluted centre J, may be employed. The well-known " Slocombe " combined centring and countersinking drill (Fig. K) held in a chuck in the back centre gives a perfect result, but it must not be used roughly, and when steel or iron is being operated on it should be freely oiled. L shows such a drill fitted in a master chuck.

The method of centring bars in vogue in modern engineering shops is to use drilling machines or centring machines having the spindles arranged horizontally, a lathe, specially adapted, answering the purpose quite well. In these machines the centre drill revolves instead of the work, which is held in a three-jaw or four-jaw self-centring chuck. The drill J is first used, and followed by the Slocombe combination drill and countersink L. The small part of the drill cuts the small hole A in Diagram C.

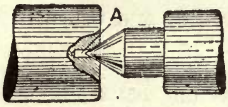
To ensure the centred bar running true after it is turned, its ends must be faced before any of the cylindrical turning is done. The tool used is shown at M, and is called a side-finishing or knife tool. It is clamped in the tool post as shown at N, and fed in the direction of the arrow A while the bar is revolving. This causes the uneven end to be faced up and all irregularities to be



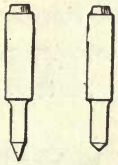

A and B.—Marking centre on bar with scribing block



D.—Centring with "Moff" callipers




C.—Correctly made centre



E and G.—Centre punches

F and H.—Centres in lathe work

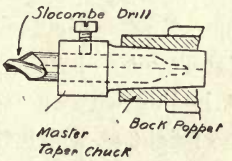
M.—Side-finishing or knife tool

I.—Square back-centre drill

N.—Tool clamped in tool post

J.—Fluted centre drill

K.—Slocombe drill




L.—Centring work with Slocombe drill

removed. B indicates the amount of material removed at one settting of the tool. When sufficient metal has been cut away, the tool is advanced by means of the cross-slide screw in the direction of the arrow C, after winding the tool post back to the first starting place along the line A. When the end is faced down the required amount, the bar must be taken out of the centres, reversed, and the other end squared up.

**Turning Cylindrical Work.** — Having squared the ends of the steel bar (an operation that may possibly necessitate the drilling of fresh centre recesses), the work is now ready for turning " over the top "—that is, cutting to cylindrical shape. A (on p. 51) shows the diamond-point turning tool, the lower dotted line indicating the probable shape after grinding many times, and the upper dotted line the shape of the tool as preferred by some turners. The sloping parts A and B and the top of the tool C are ground on a stone in order to provide a cutting edge ; the nose D is made obtuse or acute, as the worker desires. If cast-iron is being turned, a very blunt nose is necessary, and for mild steel a finer point will be required.

When fixing the tool in the tool post, it should only be allowed to project a very small amount, as at B, this position affording rigid support to the tool and minimising the liability to chatter ; the shank of the tool should be set in line with the side of the tool post.

The height at which the tool should be set is governed by the shape of the tool, the shape here considered being that shown in A. The turning tool requires to be set at a different height for nearly every diameter of material ;

thus, as the diameter of the bar is reduced by taking several cuts, the position of the tool must be altered. In ordinary turning, however, the work is so arranged that only a small amount of material has to be removed.

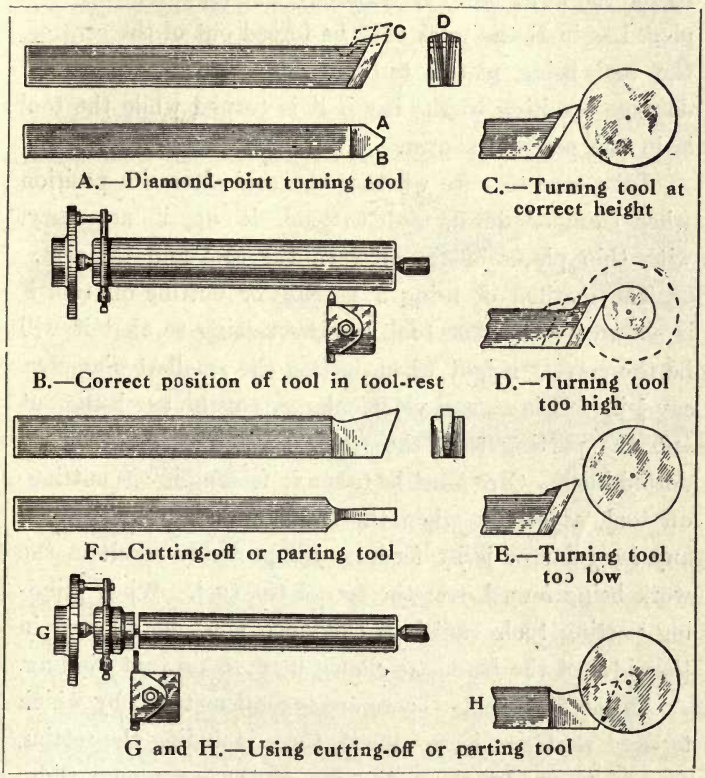



Fig. C shows an end view of a bar with the tool placed in a good position for cutting, whereas in D the tool is placed too high for cutting the bar after reduction, this resulting in the material touching the tool just below the

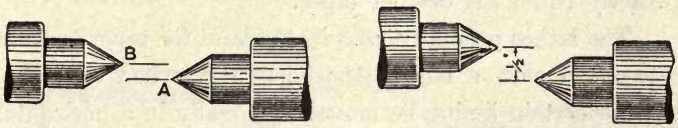
point. In D the dotted circle and tool point indicate the correct position of the tool for the large diameter, the other tool point and circle showing the impossibility of turning the small diameter with the tool placed at the same height as for the large bar. If turning is attempted with a tool placed as in E, the work may be forced out of the centres, the tool being placed too low for effective work, and damage resulting to the bar if it is turned while the tool is in the position shown.

Take care to note whether the tool alters its position when clamped down, and to pack it up, if necessary, with thin pieces of tin between the tool and the rest.

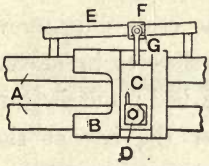
The method of using a parting or cutting-off tool F is shown by G. The tool requires setting so that it will be the correct height when cutting the smallest diameter, say $\frac{1}{4}$ in. H is an end view (enlarged) of the bar being cut and the parting tool, the latter being partly shown by dotted lines. Care must be taken in feeding-in the cutting-off tool, especially when the small diameter is reached; any irregular or jerky feeding will probably result in the work being forced over the top of the tool. When grinding parting tools sufficient clearance must be allowed in the sides of the blade, as shown in F, to prevent binding.

**Taper Turning.**—There are several methods by which tapered work can be produced, these including the setting over of the tailstock or the use of the compound slide-rest (*see also* p. 45). Where tapered work is being regularly produced, there will probably be a special lathe where the headstock and tailstock can be moved diagonally in relation to the saddle, this class of lathe being

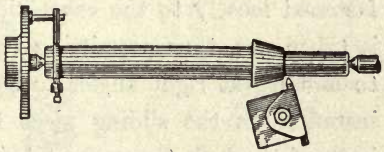
greatly used in America. A simple method is to fix the dead centre A and the live centre B out of line, as shown at A, which is a plan of the two centres placed close together. The amount by which the tailstock centre is set out of line will depend upon the taper required. For instance, if it is desired to turn a bar 12 in. long, 3 in. in diameter at the large end and 2 in. in diameter at the small end, it will be necessary to set over the tailstock $\frac{1}{2}$ in., since the bar has a total taper of 1 in. to the foot;




A and B.—Lathe centres out of line for taper turning




D.—Taper turning attachment



C.—Tool-post swivelled for taper turning

the taper on one side of the work is only $\frac{1}{2}$ in., and it thus follows that the tailstock has to be put out of line $\frac{1}{2}$ in., as shown in plan at B. When the centres are placed out of line in this manner, the tool cuts off from one side of the bar an amount of material equal to the distance that the centres are out of line.

A good method to adopt when taper pieces are required is to place a finished taper piece between the lathe centres, and then to test the taper with the point of the tool placed exactly level with the centre of the work.

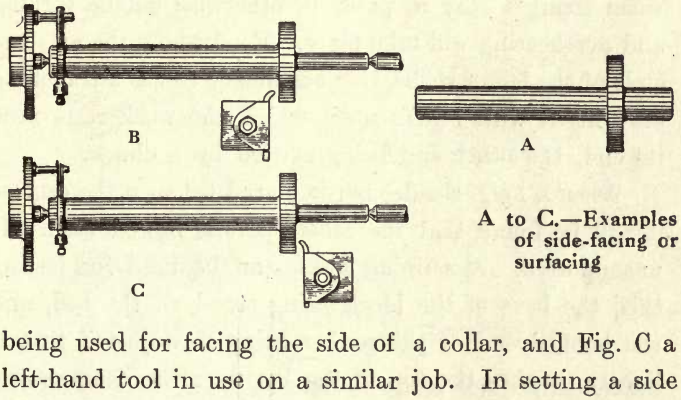
The saddle must be moved along and the work set over until the tool point just touches the work at each end.

The setting over of the centre to a great amount is not desirable, neither of the centres fitting the recess. If a great amount of taper is desired it must be turned by means of the compound slide-rest, shown at C. The tool post is swivelled round on its base sufficiently to produce the desired taper; in other words, the slope on the front of the tool post, in relation to the axis of the work, should exactly equal the desired taper.

The lathes generally used in England for taper turning are fitted with a bar at the back of the bed that can, within certain limits, be moved diagonally in a horizontal direction. Fitted on the bar is a sliding piece which is fastened loosely to the cross-slide. The cross-slide screw is taken out, thus permitting the cross-slide to be moved to and fro at right angles to the lathe bed; but in this instance, as the sliding piece fits over the bar at the back of the bed, the cross-slide cannot be moved. When any taper turning is required, the bar is set diagonally according to the amount of taper desired, and the tool fixed in the slide-rest, which is fitted with a supplementary cross-slide for the adjustment of the tool. Now, when the saddle traverse is put in motion, the saddle moves towards the headstock, and the cross-slide being attached by a sliding piece to the bar, recedes from or advances towards the centre of the work, according to the position of the bar, thus producing the desired taper. D shows diagrammatically the principle of the mechanism, A being the lathe bed, B the saddle, C the cross-slide, D the tool rest, E the

adjustable bar, F the sliding piece, and G the rod attached to the cross-slide and sliding piece.

**Surfacing.**—When large flat work is being surfaced between the lathe centres, it is usual to hold the work in a chuck and to fix an ordinary turning tool in the tool-rest at right angles to the surface that is being faced. In the case of a bar that has a collar turned on (*see* A), this would be impossible, as the work has to be machined while revolving between the lathe centres, for which purpose a side tool is used. Fig. B shows a right-hand tool




A to C.—Examples of side-facing or surfacing

being used for facing the side of a collar, and Fig. C a left-hand tool in use on a similar job. In setting a side tool it must be remembered that the smallest diameter regulates the height, and the tool must be set for this.

**Use of Stay when Turning Long Bars.** — When long and slender bars are turned a stay or support is necessary, otherwise the work may fall from the centres, and in any case accurate round bars cannot be turned. A shows a type of fixed stay that is often used. The casting A is clamped on the lathe bed B, the stay being so arranged that the top half C can be opened. The

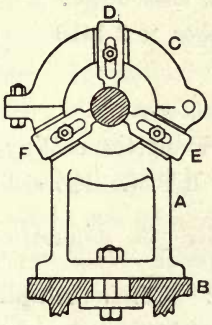
sliding pieces D, E, and F are held by means of nuts and bolts, and can be adjusted to suit various sizes of shafts.

Such a stay is used only when a short portion of a long bar requires turning. When the whole length of a long shaft is to be turned it is customary to use a travelling stay or a follower rest B, which is fixed on the saddle by means of studs passing through the holes A and B. The bar is rigidly supported close to the tool with this form of stay, and large cuts may be taken. Care is necessary when fixing a stay in position, otherwise untrue turning and overheating will take place. For turning the extreme ends of the larger shells, it is customary to use a travelling stay fitted with rollers upon which the work rests near its end, the other end being carried by a chuck.

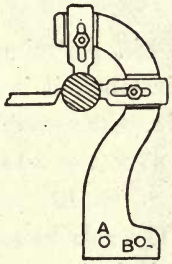
When a long, slender bar is placed between the centres it will be found that the centre part is bowed when left unsupported. A scribing block can be used for testing this, the base of the block being stood on the bed, and the hooked end of the scriber being so adjusted that it lightly touches the top of the bar near the dead centre. Next the block should be moved about half-way between the dead centre and the live centre, and the bar tested there. It may be found that the bar is bowed $\frac{1}{4}$ in. or even more. When adjusting the stay the bar must be level, otherwise it may be thrown out of the centres, and in any case the bar could not be turned parallel or round.

**Feed and Cutting Speed.** — When speaking of the amount of material that can be removed in a lathe by

means of the cutting tools, it is usual to use two terms—feed and speed, terms with which anyone in charge of a lathe will need to become familiar. "Feed" denotes the distance that the tool moves longitudinally during one revolution of the bar; "cutting speed" is expressed in feet per minute, and refers to the rate at which the work revolves in front of the tool. If a lathe were run for one minute, and the shaving produced straightened out, its length in feet would equal approximately the cutting




A.—Fixed stay




B.—Travelling stay

speed per minute, but allowance would have to be made for compression of the metal and for the breaking up of the fibre of the metal as it is removed by the cutting tool.

To determine the cutting speed, it is usual to employ a "cutmeter," shown on p. 59, which is held upon the revolving bar, and the speed indicated at the window A. It is held by means of the handle, and the wheel B, which is rubber-covered on its periphery, is driven by friction from the revolving bar. It contains a magnet mounted

upon the spindle, and is so calibrated that when the circumference of the wheel has travelled 1 ft., that distance is indicated on the dial. In engineering munitions works it is necessary to use a cutmeter constantly in order to know that the lathes are working at the maximum cutting speed.

There are other methods of determining the cutting speed, such as arriving at it by calculation. The number of revolutions per minute (R.P.M.) of the work must be counted, and the result obtained as follows:

$$\frac{\text{R.P.M.} \times \text{diameter of work in inches} \times 3{\cdot}1416}{12} = \text{cutting}$$

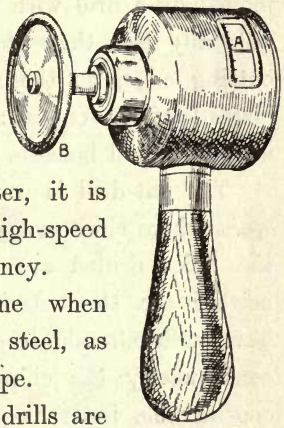
speed in feet per minute.

For instance, it is desired to know the cutting speed of a 4-in. bar revolving at 85 R.P.M. Proceeding as stated, $\frac{85 \times 4 \times 3{\cdot}1416}{12} = 89$ ft. per minute cutting speed. The rule to remember is: R.P.M. multiplied by diameter in inches, multiplied by 3·1416, and divided by 12, equals the cutting speed in feet per minute.

In some instances it may become necessary to find at what speed the work should revolve in order to give a certain cutting speed. This is especially so when the cutting speed only is known. If the cutting speed is to be 50 ft. per minute, and the work is 6 in. in diameter. the number of revolutions that the bar should make in one minute is found out thus: $\frac{50 \times 12}{3{\cdot}1416 \times 6} = \frac{600}{18{\cdot}84} =$ say, 32 R.P.M. As the shaft is 6 in. in diameter, the distance once round is $6 \times 3{\cdot}1416$, as the diameter $\times$

3·1416 equals the circumference, which is in this case 18·84 in. The distance once round the bar is 18·84 in., and the necessary speed corresponds to the number of times that 18·84 in. is contained in 50 ft. The feet have to be reduced to inches, this giving (50 × 12) 600. Dividing 600 by 18·84, 31·9 is obtained, this being the speed at which the work should revolve.

The use of high-speed steel has revolutionised metal turning, feeds and speeds now being in daily use that were a few years ago thought impossible. In ordinary circumstances, and especially when turning work of small diameter, it is quite impossible to work a high-speed tool up to the limit of its efficiency.



Cutmeter

Very little forging is done when making tools from high-speed steel, as they are generally ground to shape.

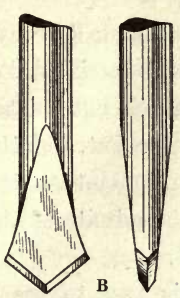
**Drills and Drilling.**—Small drills are revolved by bows, archimedean drill-holders, whirl drill-holders, and by small drill braces, and are useful for holes not exceeding $\frac{1}{4}$ in. in diameter. For larger holes it is advisable to use geared breast drills, if a drilling machine is not available. Large holes are generally drilled by means of power-driven machines, of which there are many varieties. However, in isolated instances, it may be necessary to use a ratchet drill.

The flat drill A is the type mostly used in small machine

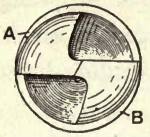
shops, and it is forged from a piece of circular bar steel. The angles A and B should be exactly equal, and the point C exactly in the centre of the drill. The clearance angles or the amount the cutting edge is backed off should be equal; the rake or clearance is clearly shown by the sloping line D. This drill can be rotated in one direction only, but that shown by B can be revolved in either direction and good results obtained. The amount of material removed by a drill with a cutting edge centrally ground is naturally less than that removed by a drill with one cutting edge, as the material is removed by scraping instead of by cutting. Drills with scraping edges are used for small holes in all kinds of metal.

The flat drill is useful for cutting cast-iron and for work where close measurements are of little importance; the holes drilled are never exactly round or parallel, neither are they straight. The cutting edges do not have sufficient rake to give them a perfect cutting action, consequently the chips are constantly broken up and considerable force has to be applied to cause the drill to cut. Flat drills are usually made from round bars of steel, with the cutting end flattened out and the other end either turned or forged to fit the drill-holder

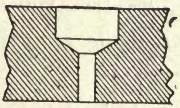
The ordinary twist drill C is made from round material. and has the flutes slightly backed off from the cutting edges, as shown in D at A and B, to prevent the drill from binding; the form of drill shown at E has clearance ground on the plates concentric with the outside of the cutting edges, as indicated at A and B. In D and E the clearance is shown exaggerated. As well as the parallel




A and B.—Two flat drills




D and E.—"Backing-off" of drill

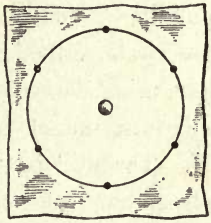


K.—Leading hole

C.—Twist drill

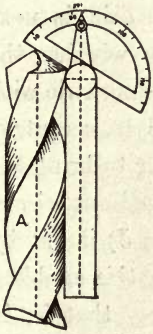
F.—Taper-shank twist drill

G.—Straight-fluted drill

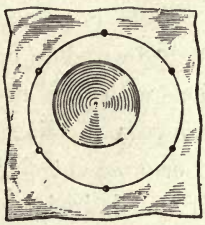


H.—Marking out for drilling

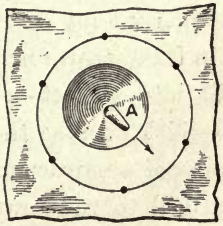
M to O.—Drill points




L.—Measuring drill angle



I




J

I and J.—Recesses drilled eccentrically

shank mostly used in lathes, and the taper shank F always used in drilling machines, there are several special drills, such as the hollow twist drill, which has a hole cut lengthwise through the shank connecting with the flutes of the drill, lubricant being conveyed to the drill point on the outside of the tube, while the hollow tube admits of the passage of oil and chips from the point.

When thin sheet-metal is drilled it is best to use a straight-fluted drill G, a twist drill tending to plunge through the material, the spiral flutes acting as a screw; straight-fluted drills are also often used for drilling brasswork.

When it is desired to drill a hole it is usual to "mark off" on the surface of the material the size of the hole required. A centre is first made with a centre-punch and a circle scribed round it by means of a pair of compasses, using the centre for one leg of the compass. Several small centre-punch marks are next made on the line, as at H. The drill is then fed down into the centre, and a small amount of material cut away; the drill is next lifted clear of the work, and note is taken whether the outside edge of the newly drilled portion is concentric with the marked-out circle. Should it prove to be eccentric, as in I, the centre must be "drawn" in order to bring the drill into correct relation with the marked-out circle, for which purpose the groove A (in diagram J) is cut by means of a narrow-nosed or cross-cut chisel, this enabling the drill to run towards the desired centre—that is, in the direction of the arrow. The chisel cut is most effective when it is deep near the desired centre, as shown

in J. After again drilling away a small amount of material, it will be found that the drill has changed its position, and if it has not moved sufficiently, more chisel cuts must be made until it is correct.

In drilling deep holes it is often advantageous to drill first a small hole right through the material K in order to take the strain off the point of the drill. As already explained, the action at the point is only of a scraping nature, and if a large drill is used considerable effort will be required to force it into the material.

Regarding the speed of the drill, if no method is available for indicating the number of revolutions per minute, the condition of the cutting edges may be observed after the drill has done a little work. If the cutting edges are chipped, it is an indication that too much pressure or feed has been applied; if the corners are worn, it is an indication that the drill is revolving at too quick a speed. Of course, unless the drill is correctly hardened the above observations will be of little use, since ordinarily a hard drill would badly chip and a soft drill would badly wear. It is, therefore, essential that the drills should be correctly hardened.

The speeds given in the table on p. 64 are those recommended by one of the largest manufacturers of twist drills in the world. The feed recommended is ·004 in. to ·007 in. per revolution for drills that are smaller than $\frac{1}{2}$ in. diameter, and from ·005 in. to 010 in. for drills larger than $\frac{1}{2}$ in. diameter.

The table on p. 65 has been given by the makers of the well-known "A. W." high-speed drills, and is

arranged for ordinary grades of mild steel and cast-iron. When drilling brass, the speeds may be increased 100 per cent.—that is, multiplied by 2—and for cast-iron the feeds may be increased 25 per cent. for all drills above $\frac{3}{4}$ in. diameter. From the table given it appears that a $\frac{1}{4}$-in. drill will drill through mild steel at the rate of $8\frac{1}{2}$ in. per minute, and a $\frac{3}{4}$-in. drill at the rate of nearly 4 in. per minute. The cost of high-speed drills is about twice that of ordinary tool-steel drills, but the extra cost is saved in a big establishment after using for a few minutes.

With regard to the grinding of twist drills, if the clearance of a twist drill is insufficient or imperfect, the tool

SPEEDS OF TOOL-STEEL TWIST DRILLS

| *Size of drill* | *Revolutions per minute* | *Size of drill* | *Revolutions per minute* | *Size of drill* | *Revolutions per minute* |
|---|---|---|---|---|---|
| $\frac{1}{16}$ | 1,834 | $1\frac{1}{16}$ | 108 | $2\frac{1}{16}$ | 55 |
| $\frac{1}{8}$ | 917 | $1\frac{1}{8}$ | 102 | $2\frac{1}{8}$ | 54 |
| $\frac{3}{16}$ | 611 | $1\frac{3}{16}$ | 96 | $2\frac{3}{16}$ | 52 |
| $\frac{1}{4}$ | 458 | $1\frac{1}{4}$ | 92 | $2\frac{1}{4}$ | 51 |
| $\frac{5}{16}$ | 360 | $1\frac{5}{16}$ | 87 | $2\frac{5}{16}$ | 49 |
| $\frac{3}{8}$ | 306 | $1\frac{3}{8}$ | 83 | $2\frac{3}{8}$ | 48 |
| $\frac{7}{16}$ | 262 | $1\frac{7}{16}$ | 80 | $2\frac{7}{16}$ | 47 |
| $\frac{1}{2}$ | 229 | $1\frac{1}{2}$ | 76 | $2\frac{1}{2}$ | 45 |
| $\frac{9}{16}$ | 204 | $1\frac{9}{16}$ | 73 | $2\frac{9}{16}$ | 44 |
| $\frac{5}{8}$ | 184 | $1\frac{5}{8}$ | 70 | $2\frac{5}{8}$ | 43 |
| $\frac{11}{16}$ | 167 | $1\frac{11}{16}$ | 68 | $2\frac{11}{16}$ | 42 |
| $\frac{3}{4}$ | 153 | $1\frac{3}{4}$ | 65 | $2\frac{3}{4}$ | 41 |
| $\frac{13}{16}$ | 141 | $1\frac{13}{16}$ | 63 | $2\frac{13}{16}$ | 40 |
| $\frac{7}{8}$ | 131 | $1\frac{7}{8}$ | 61 | $2\frac{7}{8}$ | 39 |
| $\frac{15}{16}$ | 122 | $1\frac{15}{16}$ | 59 | $2\frac{15}{16}$ | 39 |
| 1 | 115 | 2 | 57 | 3 | 38 |

will not cut. When force is applied the drill resists the power of the machine, and in consequence is crushed or split. It is well to start a drill by hand after grinding, observing the character of the chips, which should show if the drill is cutting correctly; in wrought-iron, when the drill is cutting correctly, the shaving will sometimes attain a length of several feet.

Twist drills properly made have their cutting edges straight when ground to a proper angle, which is 59°, as in L (p. 61). Grinding to a less angle produces a drill

SPEEDS AND FEEDS FOR HIGH-SPEED-STEEL TWIST DRILLS

| *Size of drill* | *Revolutions per minute* | *Feeds* | | *Size of drill* | *Revolutions per minute* | *Feeds* | |
|---|---|---|---|---|---|---|---|
| | | *Per rev. in in.* | *Per minute in in.* | | | *Per rev. in in.* | *Per minute in in.* |
| $\frac{1}{4}$ | 1180 | ·0072 | 8·48 | $1\frac{3}{8}$ | 198 | ·0127 | 2·51 |
| $\frac{5}{16}$ | 940 | ·0078 | 7·28 | $1\frac{1}{2}$ | 180 | ·0131 | 2·37 |
| $\frac{3}{8}$ | 780 | ·0083 | 6·45 | $1\frac{5}{8}$ | 165 | ·0135 | 2·23 |
| $\frac{7}{16}$ | 666 | ·0087 | 5·79 | $1\frac{3}{4}$ | 151 | ·0138 | 2·07 |
| $\frac{1}{2}$ | 580 | ·0091 | 5·27 | $1\frac{7}{8}$ | 140 | ·0141 | 1·97 |
| $\frac{9}{16}$ | 513 | ·0095 | 4·84 | 2 | 130 | ·0144 | 1·88 |
| $\frac{5}{8}$ | 460 | ·0098 | 4·51 | $2\frac{1}{4}$ | 113 | ·0150 | 1·69 |
| $\frac{11}{16}$ | 416 | ·0101 | 4·2 | $2\frac{1}{2}$ | 100 | ·0155 | 1·56 |
| $\frac{3}{4}$ | 380 | ·0104 | 3·96 | $2\frac{3}{4}$ | 89 | ·0160 | 1·43 |
| $\frac{13}{16}$ | 349 | ·0107 | 3·71 | 3 | 80 | ·0165 | 1·31 |
| $\frac{7}{8}$ | 323 | ·0110 | 3·55 | $3\frac{1}{4}$ | 72 | ·0170 | 1·22 |
| $\frac{15}{16}$ | 300 | ·0112 | 3·37 | $3\frac{1}{2}$ | 66 | ·0174 | 1·14 |
| 1 | 280 | ·0114 | 3·22 | $3\frac{3}{4}$ | 60 | ·0178 | 1·07 |
| $1\frac{1}{8}$ | 247 | ·0119 | 2·94 | 4 | 55 | ·0182 | 1·0 |
| $1\frac{1}{4}$ | 220 | ·0123 | 2·72 | | | | |

that will cut a crooked and irregular hole. The grinding line A on a drill is placed slightly above the centre, to allow for the proper angle of the point. The angle is an index to the clearance. If it is too great the drill cuts badly; if not enough, the drill may not cut at all. M indicates the correct angle; in N, the angle is too sharp; in O, the angle runs backwards and shows the want of clearance.

An effective method of determining the clearance is to set the point of the drill on a flat surface, holding a scale as at P (opposite); by turning the drill round, its clearance is shown, as well as the height of the cutting lips, which height should be equal. The cutting edges should be of exactly equal length, since the effect of the inequality is doubled in working.

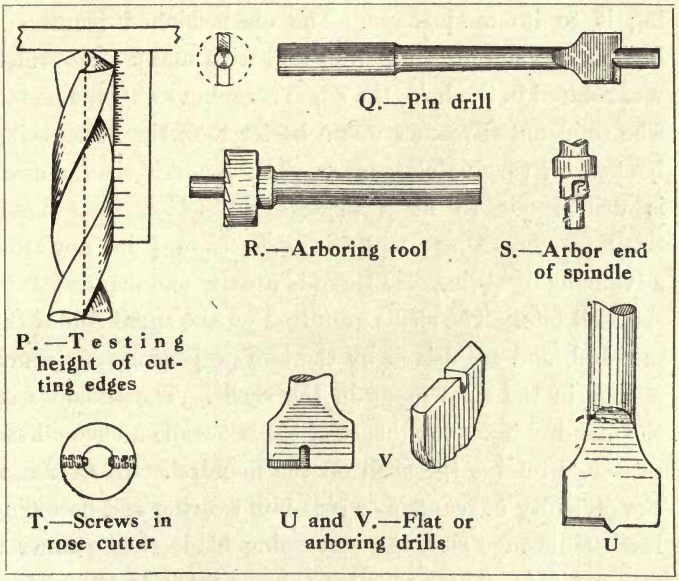
Special twist-drill grinders make the re-grinding of these drills a simple matter.

*Other Drills.*—When a hole is bored through a casting or other machine part, the surface round the hole is usually arbored to form a flat, smooth bearing for the nut or bolt head to bed on, and for this purpose a pin drill Q is used. The pin enters the hole, and steadies the drill. The flat cutters true up the surface, or bore it deep enough to receive cheese-headed screws.

Another form of arboring tool R consists of a loose rose-head cutter, quickly attached to a mandrel or shank to fit the drill spindle. The lower end of the mandrel has two small keyways or grooves opposite each other, and they also turn at right angles at the top ends (*see* S). The loose rose cutter is provided with two internal pro-

jections made by tightly fitting screws, as shown in T. These projections fit up into the vertical grooves shown in S, and then a slight turn carries them into the horizontal grooves, the rose head being thus retained in its working position.

Other forms of rose-head cutters are in use for counter-




sinking and forming the coned seatings for small valves, etc.

It frequently happens that holes are required with flat bottoms, and to effect this a flat or "bottoming" drill is used to follow after the ordinary cone-pointed drill. The form of flat drill shown by U has a short centre spur of diamond-point shape, the cutting edges and sides

being backed off as usual for clearance. In the flat drill shown by V, the spur is replaced by a slot cut at an angle with the edges of the drill, so that the inner cutting lip of one side will just lap the inner edge of the opposite lip, and so leave a clean surface on the work.

**Reamers.**—The reamer—known also as rimmer, rhymer, etc.—is a tool for truing or enlarging a hole and bringing it to its final shape. The old-fashioned reamer or broach was simply a tapering tool with many sides which was rotated in the hole, the edges scraping away the metal. The solid fluted reamer was a better tool, the flutes being backed off to give clearance. The modern shell reamer is drilled out to fit a mandrel on which it is used. Shell reamers A are made in sizes from $\frac{1}{2}$ in. upwards, advancing by $\frac{1}{16}$ in., and there is usually one mandrel B to six shell bits. The shells are fitted on the small end of the mandrel, and are driven by the two projecting pegs which engage in the slots made in the shells. The shoulder on the mandrel takes the thrust of the cut while a cheese-head set-screw retains the shell on the mandrel. To overcome the difficulty of reamers or rose bits wearing and becoming less than gauge size, the expanding blade shell reamer C was devised. These reamers are not made in the smaller sizes, as it would be impracticable to do so. In the reamer shell are spaced and formed six longitudinal grooves having a very slight taper, and with a very slight undercut or dovetail in the grooves. In the latter the steel cutter blades are tightly fitted. As wear takes place, the blades are touched up on the oilstone, and forced farther up the grooves. The taper in them forces out the blades a little

more ; the limit of expansion is ·004 in. to ·008 in., according to the size of the shell. When the blades are much worn new ones can be inserted at small cost. D shows a hand reamer of the expanding type on similar lines to those already described.

**Drilling and Boring in the Lathe.**—So much of the work of shell making consists in boring and reaming in the lathe that some general information on the subject, applicable to a multitude of purposes, will be acceptable.

Ordinary flat drills for use in the lathe can be made

B.—Mandrel for shell bits

A.—Shell reamer

D.—Expanding reamer

C.—Expanding reamer

from old files to the shape shown at A (p. 71) ; as far as the point is concerned, the shape is exactly the same as for use in a drilling machine, but there is a difference in the shape of the shank. Old files are not superior to ordinary bar material for making drills ; indeed, the reverse is the case, but it is economical to use up old material in this manner.

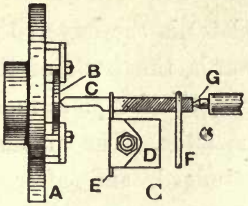
When drilling small holes in a disc, it is better not to clamp the drill in the tool post, but to use it in the manner about to be described. A piece of bar iron or steel is slotted as shown at B, and clamped in the tool post as

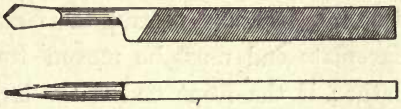
in C. The drill is then passed partly through the slot, the point of the drill being forced against the work by means of the tailstock centre, which fits into a recess already provided in the end of the drill. In order that the drill may start true, the hooked bar D is slipped over the drill at the tailstock end, and lifted up and down (as the work revolves) as far as the limits of the slotted bar will allow. A reference to Fig. C will make clear the method of working. The faceplate is shown at A, the disc at B, the drill at C, the tool post D, the slotted bar E, the hooked bar F, and the tailstock centre G.

For enlarging the hole a lipped drill E is clamped in the tool post direct, and fed into the work by means of the tailstock centre, as in Diagram F. The saddle can be used for feeding-in the drill, but this method is not advised. The drill has a tendency to bend upwards between the drill point and the tool rest if the saddle is forced along by means of the handle used for hand traversing.

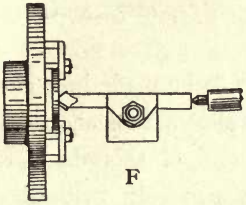
For a large hole or for a truly circular hole it is customary to use a boring tool, which is shaped as shown in G. It should be clamped in the tool post in the lowest possible position, so as to ensure a good cutting angle. Of course, the shape of the tool must be made to suit the material being bored. For instance, a blunt nose is desirable for cast-iron, and a somewhat finer point for mild steel.

It frequently happens that a bored hole is not perfectly parallel. It will then be necessary to move the headstock towards or away from the worker, according to which end of the hole is larger. If the back end of

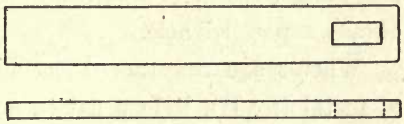


A.—Lathe drill made from flat file



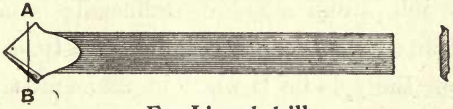
F



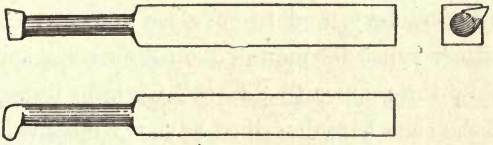
B.—Slotted bar

C and F.—Drilling in the lathe

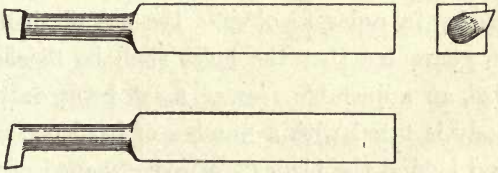
D.—Hooked bar for drill




E.—Lipped drill



G.—Lathe boring tool



H.—Recessed work

I.—Cornering tool

the hole (the end nearest the faceplate) is the larger, the faceplate end must be moved towards the back of the lathe; if the front end is the larger, the faceplate must be moved towards the front of the lathe. The amount of movement necessary must be judged, and after a few holes have been bored it will be an easy matter to obtain a parallel hole.

When a square-cornered recess is to be made in a piece of metal (*see* H), it is usual to employ a tool shaped as shown at I; some workers use a tool of this shape for smoothing out the hole, but if a perfectly cylindrical, smooth, and parallel hole is desired a reamer must be used.

It is possible to bore a parallel hole without the aid of a reamer, but the job is difficult, and, ordinarily, is not attempted. An ordinary shell reamer is shown at A (p. 69), this being fixed on the spindle B when in use, and the spindle fitting into the tailstock barrel or being arranged to fit in the tool rest. However, both these methods are unsatisfactory, and to ensure a correctly shaped hole the reamer must be mounted on a floating spindle, so as to allow the reamer to "float" while in use. Shell reamers of the class here described have the disadvantage that they soon wear, and are then useless, inasmuch as the finished hole is smaller in diameter than when the tool is first used. In order to obviate the use of shell reamers, and to guarantee that the holes shall be finished a standard size, an adjustable reamer must be used. The mild steel body is fitted with a number of hardened cutting blades, and behind the blades are wedge-shaped pegs. When the reamer is cutting a small hole, that is, a hole under the

standard size, the pins are each driven in a corresponding amount. This causes the blades to move away from the centre and to increase their collective diameter. The reamer can then be ground up afresh. In use, this form of expanding reamer is fixed on a mandrel similar in shape to that used for the shell reamer.

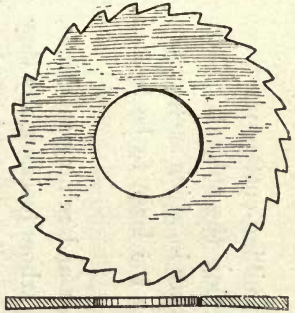
**Milling.**—This is a method of cutting or shaping metal by means of cutters that revolve about their own axes. Such cutters are used in lathes, or, more properly, in special milling machines which are made in great variety. Milling cutters themselves may be of the one-tooth variety, in which case they are known as fly cutters, or they may have a great number of teeth—say, about thirty or so—which teeth may be cut in the solid metal or may be inserted, the latter type of cutters being used chiefly for roughing out. The width of the cutter may vary from a fraction of an inch to as much as 24 in. or so, but it is not usual to have wide cutters solid, but rather to build them up as a "gang" carried by an arbor or spindle with a trifling clearance between them. Milling cutters need to be very amply lubricated in use. They may be employed to produce plain flat work or work in a variety of profiles or contours. For wide flat work, milling cutters are employed simply for roughing out, the finishing cut being taken in a planer; but for profile work, the milling cutters both cut and finish.

As a rule the work is stationary, but there is one branch of milling in which the work—chiefly pulleys and wheels—revolves as well as the cutters, the direction of rotation being the same (anti-clockwise), so that as

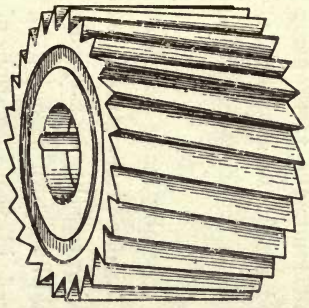
the cutter teeth descend, the periphery of the work is ascending.

Milling cutters are used in a very great variety of sizes and shapes, and the names by which these shapes are known vary sometimes in different shops. The face cutter, otherwise the plain, cylindrical, common or parallel cutter, will be known at once by its resemblance, in the narrow sizes, to a circular saw; indeed, it is commonly used as a metal-slitting saw A, for which purpose it is used as thin as, or even thinner than, $\frac{3}{64}$ in., and in diameter up to 5 in. or more. It is thicker towards its edges, so as to provide side clearance when cutting. When the thickness of this slitting saw is multiplied many times, there is produced the plain, common, or cylindrical cutter B, which in its small sizes up to 1 in. wide may have straight teeth, but in the larger sizes generally has helical (commonly called spiral) teeth, which are adopted in order to avoid chattering. Plain cutters are obtainable in variety, with or without inserted blades or even inserted teeth, with nicked teeth, etc. Inserted blades or teeth may be of high-speed steel and the body of the cutter of a cheaper steel. Nicked blades resemble C, and their advantage is that they can take a deeper cut for the same expenditure of power, owing to the fact that the chips are broken up and less metal is compressed; of course, the nicks in the successive edges are staggered, as otherwise the cutter would at once become a profile cutter and simply cut a number of grooves in the work.

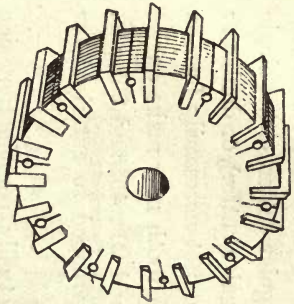
The next chief type of milling cutter is the side cutter, which is generally combined with the cylindrical cutter,



A.—Slitting saw

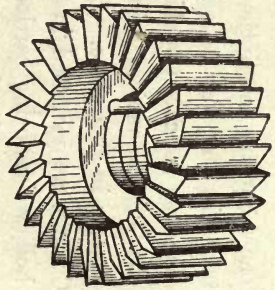


B.—Parallel milling cutter



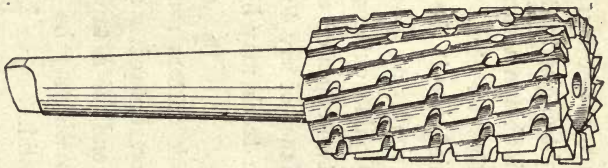
E.—Inserted blade cutter

G.—V-cutter

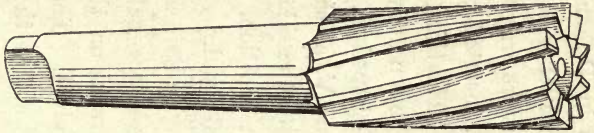


D.—Combined side and face cutter

F.—Angular cutter



C.—Shank cutter, nicked



H.—Shank cutter, helical fluted

as in D; such a cutter can be applied to work either parallel or at right angles to its own axis. As before, side cutters are obtainable in a variety of types, inserted blade E, inserted tooth, etc. etc.

The third chief class is the angular cutter, either single F (often known simply as the angular cutter), or double or V-shaped G. Double cutters do not necessarily form a true V, as the two edges of each tooth may make angles with the side planes of say 40° and 20°, 45° and 30°, etc. In addition, the teeth may be arranged to cut right- or left-hand.

End or shank cutters are actually combination side and face cutters, but of a solid kind, the teeth being formed on the end of a tapered shank, as shown at C and H. The teeth may be straight or helical, inserted or cut in the solid.

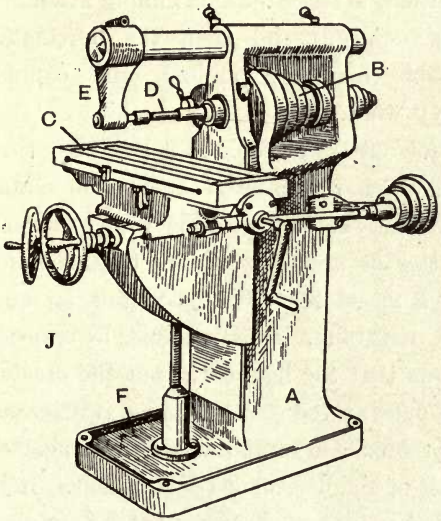
Profile or form cutters are generally made to meet special requirements. They may be one-piece cutters I, or consist of a series of cutters working together on a spindle or arbor, in which case they would be known as a "gang cutter." Profile cutters are used in the formation of gear-wheel teeth.

The foregoing descriptions of milling cutters must not be taken in any way as exhausting the subject. These notes merely indicate the chief types in which such cutters are made; the subject being far too large to be treated adequately in this place.

Cutters are mounted in lathes and milling machines, the hollow ones being carried by arbors (occasionally they are solid with them), and are generally clamped in place

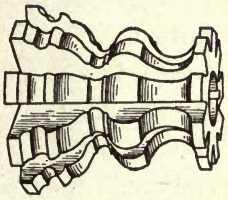
by means of collars, keys, etc. Screwing, without some further means of attachment, is not enough, as the arbor can then revolve only in one direction without the cutter getting loose.

The machines on which the cutters are used are known as milling machines, and are found in a great variety of types, scores of special designs having been evolved to




I.—Form or profile cutter

J.—Milling machine with horizontal spindle



I

suit particular needs—cam shaping, gear cutting, etc. J shows a design that is applicable to many ordinary purposes. A substantial standard A carries the four-step pulley B and the table C, the last mentioned being capable of moving lengthwise, crosswise, or vertically, and being controlled by the various handles shown. The mandrel driven by the pulleys is hollow, and can take either a solid shank cutter or a spindle or arbor D to carry a hollow

cutter, the outer end of the spindle being supported in a bearing in the overhanging arm E, which arm can be swung up out of the way when not required. Lubricant (preferably oil, although soapy water and other mixtures are commonly used) is very freely employed, and it is therefore necessary to provide an ample tray F to catch the waste lubricant, chips, etc.

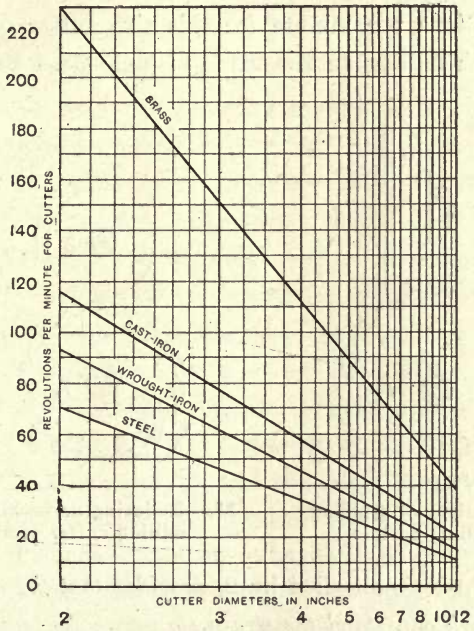
There is, in addition, a vertical-arbor milling machine, but this is less generally useful than the horizontal type, is not suitable for gang milling, and cannot negotiate such heavy work.

The best speed for cutters or tools in a lathe or other machine is that at which the greatest amount of metal can be removed in the shortest possible time, without overheating the cutter or unduly straining the machine. To arrive at such a speed for different metals on any particular machine, naturally, is only found by experiment. It also follows that the lighter the cut the greater the speed. Heavy cuts at too great a speed will cause either a softening or breakage of the cutter, or a chatter and strain from lack of rigidity, or a slipping belt. It is found in practice that more metal can be cut by running the machine at a fast speed (according to the nature or hardness of metal), and putting on the deepest cut and coarsest feed the machine and material will stand without springing or straining. Better results are thus obtained than by running at a slow speed with still deeper and coarser feeds.

The peripheral speed of milling cutters in inches per minute is as follows: For cast-iron, 680 to 700 steel,

420 to 475; wrought-iron, 500 to 560; gunmetal, 550 to 950; brass, 950 to 1,500. On finishing cuts the speed may be increased from 20 per cent. to 30 per cent.

In milling cast-iron the work is not so cleanly done

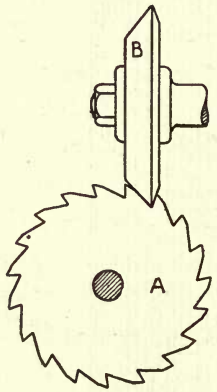



**K.—Speed graph for milling cutters**

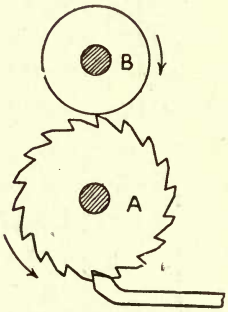
when the milling cutter turns against the direction of the feed, as when the cutting edges follow the same direction; but in the latter case the amount of work in a given time is less.

The diagram shown by K is useful for finding at a glance the speed of milling cutters from 2-in. to 12-in. diameters

for steel, wrought-iron, cast-iron, and brass. To use the table or diagram, take, for example, a cutter of 3-in. diameter for cast-iron. On the base line of the diameters find 3 in., run it up until it meets the oblique line marked cast-iron, and where it intersects trace horizontally to the left to the line of revolutions, and it will read seventy-six revolutions per minute for this size cutter on cast-iron. With milling cutters made of high-speed steel, the




L.—Method of grinding milling cutters




M.—Relieving or backing off milling cutter teeth

speed might be multiplied by 2, *provided that the machine and the work can stand the strain.*

L shows the method of re-grinding milling cutters A by special-shape emery wheel B, and M the method of relieving or backing off the teeth of the cutter A with a small diameter emery wheel B driven from the overhead gear. The cutter is mounted between centres, and a suitable stop is rigged up to steady the cutter against the thrust of grinding.

**Planers and Shapers.**—In the planer the metal work is planed, a narrow strip at a time, being clamped or otherwise very securely fixed to a substantial travelling table, which is caused to pass under a vertical tool carried by a horizontal cross rail, itself supported in uprights termed "housings." The tool has a single cutting edge and resembles a simple lathe tool; it will be noted that it remains stationary and the work moves. On the return motion the tool swings out of operation, and a cross feed brings it into position for the next trip of the work. As a rule, the roughing is done at one operation, and a finishing cut taken later. The heavy sliding table is operated by rack and pinion, or by means of a screw running lengthwise of the machine and working in a nut attached to the table, there being provision for a quick return which is, of course, an idle stroke (in all ordinary machines). The reversing of the direction is accomplished automatically by reversing levers which shift two belts (one from a fast to a loose pulley and the other from a loose to a fast), the moment of reversal being controlled by a stop. Planers and shapers have much in common, but in the latter—the lighter machine of the two—it is the tool that moves to make the cut, and the cross feed is frequently obtained not by sliding the tool, but by sliding the work. No lengthy description of the shaper will be attempted, the variety of such machines being far too great. Ordinarily, the table can move in two horizontal directions as well as vertically, but vertical feed is applied to the tool; as regards horizontal feeds, these may be operated through tool or table, according to the size and

type of machine. The shaper has lost much of its importance by the rise into general favour of the now highly-developed milling machine; this applies particularly to the use of the shaper as a slotting machine, the last-named being a type of shaper in which the tool is given a vertical cutting movement, the idle stroke coming on the up-stroke.

**Gear Cutting.** — Whilst gear cutting in quantity is always done on special machines, it is useful to know that a spur gear-wheel can be cut in a screw-cutting lathe, providing there are at hand the necessary attachments for the purpose. First method: a milling cutter of correct shape and size of space between the teeth of the proposed spur wheel is fixed to an arbor or mandrel between the lathe centres, and driven with the back-gear in. Then on the surfacing slide of the slide-rest or saddle is secured a vertical slide carrying an attachment with a fixed head, on which is a division plate or counter for moving the blank wheel round the exact amount for the next tooth space to be cut. The wheel is, of course, driven on a short mandrel, the top end of the latter being attached to the spindle of the dividing apparatus, while the bottom end is fixed to a back centre or small poppet similar to the poppet of the lathe itself. It will be obvious by this method that only a limited diameter wheel could be cut.

The second way is to mount the wheel blank on a mandrel between the lathe centres, and use a milling cutter fixed on a vertical spindle on which is a worm wheel driven by a worm on a horizontal spindle with a small pulley for a $1\frac{1}{2}$-in. belt driven from overhead gear. The whole apparatus is in a frame (styled a milling-cutter frame),

and is fixed in the slide tool-holder. With this arrangement a dividing apparatus is also necessary.

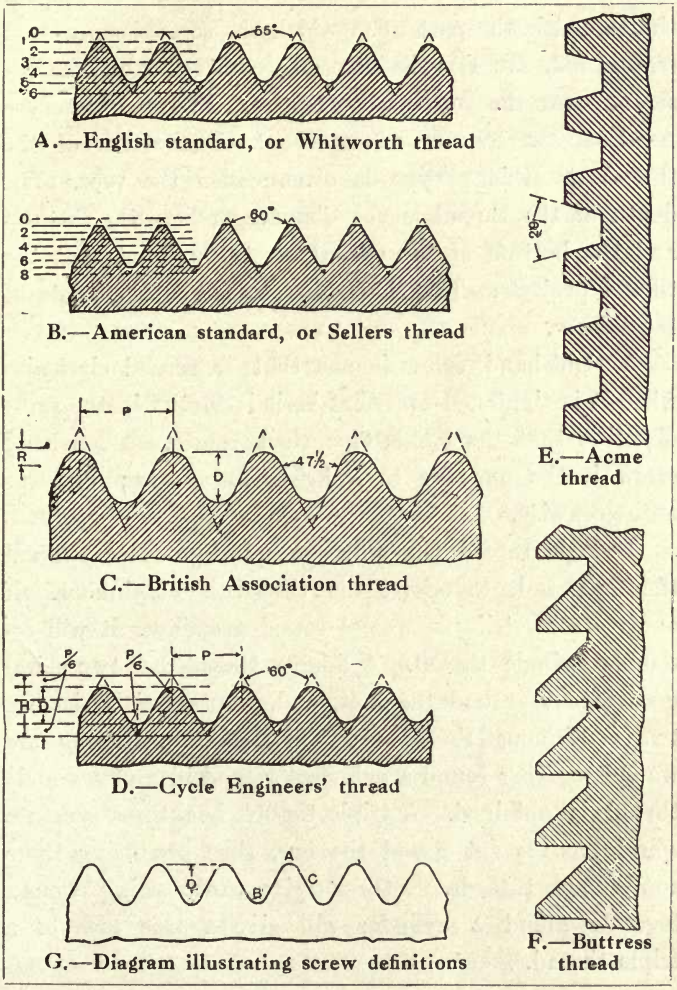
A third method, and probably the way it would be expected for a workman to perform it as a makeshift or improvised job, is as follows: Mount the wheel blank on a spindle between the lathe centres, holding the spindle rigid in the four-jaw chuck. Now assuming the wheel to be cut contained twenty teeth, then if a 20-toothed wheel were fixed on the lathe spindle and an improvised " stop " or counter fitted to spring into the space between the teeth, then, by lifting back the stop and turning the lathe spindle one tooth and dropping the stop again, the wheel blank would be moved with it the correct distance for another space to be cut. The actual cutting is done as follows: A tool similar to a round-nosed parting tool is fixed on its side in the tool holder and fed by the surfacing slide, but the cut is taken as in a shaping machine, by moving the saddle forwards and back by means of a long wrench or hydraulic-jack handle fixed to the rack-and-pinion motion of the saddle. After the twenty divisions have been cut to the required depth, a second, a finishing, tool is used, filed, of course, to the correct curves of the tooth profiles, and used to skim up the spaces in the same manner. This method, while not requiring any elaborate apparatus is still rather a tedious method of performing the work; but with reasonable care the work should be fairly accurate. The correct diameter of the wheel blank and the pitch line, depth of tooth spaces, etc., are first obtained by mathematical formulæ, but the lathe hand is not expected to work these out. He might have to make a wheel

similar to a broken one given as a pattern. If so, possibly it could be rigged up on the same mandrel and used for dividing by the improvised stop previously mentioned. The Pittler lathes supplied to the "service" have special wheel-cutting and milling apparatus suitable for small gears.

**Screws and Screw-threads.** — The Whitworth, or English Standard thread, is shown at A, the angle being 55°. One-sixth of the height from 0 to 6 is rounded off at the top and bottom of the thread in order to prevent damage and to reduce the risk of the bolt breaking at the root of the thread. The American Standard, or Sellers thread B is made with an angle of 60°, and one-eighth of the height, 0 to 8, is cut off the top and bottom, leaving a flat one-eighth of the pitch in width. The British Association thread C is used for small screws. The angle of the thread is 47½°, and the top and bottom are both rounded to the same radius, this being two-elevenths of the pitch. In diagram C, D equals depth, P the pitch, and R the radius of the bottom and top of the thread. There are other standard threads.

The thread adopted by the Cycle Engineers' Institute (*see* D) has an angle of 60°, and has the top and bottom of the thread rounded; H equals 0·866 of the pitch P, and D equals 0·5327 of the pitch. The smallest size has 62 threads per inch, and the largest size had 24 threads per inch. The Acme thread E is largely used in machine tools, such as screw-cutting lathes where a disengaging nut is fitted. The angle is 29°, and this has been almost universally adopted as the angle for worms such as are used

in reduction gears. The buttress thread (Fig. F) has one side at an angle of 45° and the other side vertical; this form of thread is often used in mechanism where the



thrust or wear comes in one direction; hydraulic presses and heavy siege guns are examples of such machines.

Square threads are so arranged that the depth and width of the thread are equal to the space. The top of the thread is the part upon which the screw is measured (*see* A, diagram G); it is usual to measure all English screws over the tops of the thread. In some instances American screws are measured at the bottom of the thread B; this portion is often called the root. The depth of the thread is the distance D between the top and the bottom of the thread, or the amount that the thread projects. The slope of a thread is the angle of the sides C.

A right-hand screw is one that is turned clockwise when it is tightened up—that is, it is turned in the same direction that the hands of a clock rotate. A left-hand screw is the opposite to a right-hand screw; it turns anti-clockwise.

A single thread has only one spiral groove cut round the bar, and, therefore, the thread is continuous. If one piece of string is wound round a cylinder it will resemble a single thread. A double thread has two spiral grooves cut around the bolt, and, consequently, it has two continuous threads. If two pieces of string are wound together round a cylinder, a good idea of a double thread is obtained. A triple thread has three separate spiral grooves cut round the bar, thus producing three continuous threads. Three pieces of string wound together round a cylinder will give a true idea of a triple thread.

**Screw-cutting.**—External screw-threads may be cut by several methods: (1) By hand dies A (for single threads), in which the die is generally passed over the material once or several times in order to cut a full thread. Dies are held in stocks, B. This method does not require a lathe; whereas for the following methods a lathe or other machine is necessary: (2) By machine dies (C), which are passed once only over the work in order to cut a full thread; often the die is so made that when it has screwed far enough, the cutting blades automatically open, and so allow the die to be returned rapidly to the starting position. (3) By hand chasers D, which are lathe tools frequently used in brass work. (4) By single- or multiple-pointed tools E and F, which are held in the slide-rest tool post of a screw-cutting lathe. In E, A is the work, B and C the lathe centres, D the single-pointed tool, and E a setting gauge consisting of a piece of sheet steel, the notches in which vary according to the screw to be cut. In F, A, B, and C are as before, D the multiple-pointed tool, E a square for correctly setting the tool horizontally, and F the tool post.

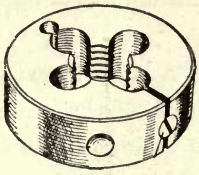
Internal threads are cut (1) by hand taps G, H, and I; (2) by collapsible taps, which close inwards and permit of their withdrawal from the hole; in order to get the tap out, solid taps require to be reversed or the work to be turned backwards; (3) by hand chasers J, which, as in the case of external threads, are much used for brasswork; (4) by single- or multiple-pointed tools K and L held in the tool post slide-rest. In diagram K, the sheet-steel gauge for testing the setting of the single-point tool is

shown ; and in L, A is the work, B a square for checking the horizontal setting of the chaser C, D is the tool holder, and E the tool-rest of the slide-rest.

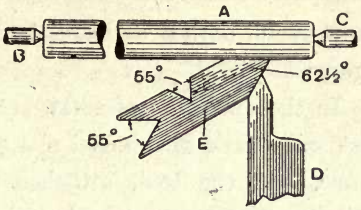
Screws required in huge quantities are made on automatic screw-cutting machines and in works where little else is likely to be done. The machines are highly complicated, due to the provision of mechanism for feeding, stopping, adjusting, and controlling the work quite automatically.

**Change Gears of Screw-cutting Lathes.** — While there is no space here to describe in detail the practical work of screw-cutting on ordinary lathes, it is thought desirable that the reader should be instructed as to the principle on which the work is done. The Editor of this handbook frequently receives requests for enlightenment as to the arithmetical calculations that underlie the production of a screw of a given number of threads per inch. A lathe-cut screw (none other is at all accurate) is a copy of the leading screw (often called " lead screw "). English lathes are fitted with a leading screw of two threads per inch (or $\frac{1}{2}$-in. pitch), and supplied with a set of twenty-two change wheels rising by five teeth, the smallest having twenty and the largest 120 teeth ; the set always includes either two forty-tooth gears or two sixty-tooth gears for cutting screws of the same pitch as the leading screw. In some small lathes leading screws with four threads per inch are fitted. In many American lathes the leading screw has four or six threads per inch, and the change gears have teeth arranged in multiples of four.

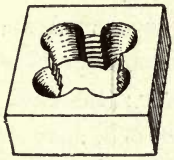
The principle of calculating change wheels is exactly



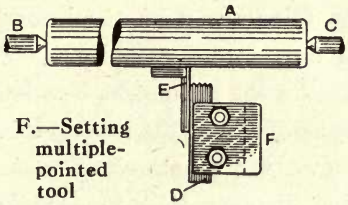
A.—Adjustable die




E.—Setting single-pointed screw-cutting tool

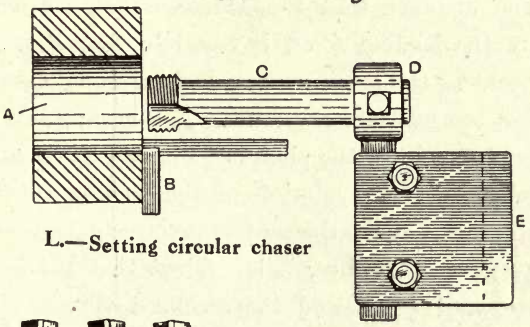


C.—Machine die

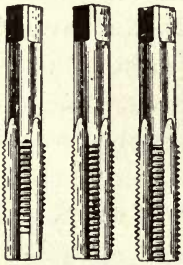



F.—Setting multiple-pointed tool

B—Die stocks

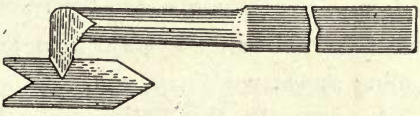



L.—Setting circular chaser



G to I.—Taper, second and plug taps

D and J.—Hand chasers for external and internal threads



K.—Testing internal tool

the same for both British and American lathes, but different figures are used.

In the operation of screw-cutting in a lathe the slide-rest and saddle are moved along by means of the leading screw, and the tool, attached to the slide-rest, moves with it. The rate at which the slide-rest and the tool move is governed by the change wheels that are fitted on the lathe spindle and on the leading screw. A split nut is fitted on the saddle, and can be opened or closed at any period by the movement of a handle; the closing of the nut causes it to fit the leading screw, and, as a consequence, moves the saddle along when the screw is revolving. The distance that the saddle travels for one revolution of the leading screw is equal to the pitch of the thread, and as the leading screw has only one thread the pitch and the lead are the same. If a leading screw has two threads per inch, the pitch is $\frac{1}{2}$ in., and the saddle moves $\frac{1}{2}$ in. for every revolution of the leading screw. If the work between the lathe centres revolves once while the leading screw turns once, it is evident that the tool will move forward $\frac{1}{2}$ in., and the resultant thread will have a pitch of $\frac{1}{2}$ in.; in other words, the number of threads cut in the work will be exactly equal to the number of threads per inch on the lead screw, in this case two. If the lathe spindle and the work revolve four times as fast as the leading screw, the resultant screw will have four times as many threads in a given distance as the leading screw.

For example, the leading screw has two threads per inch, and a length of 1 in. has been screwed; then the

finished screw will have $4 \times 2 = 8$ threads per inch and a pitch of $\frac{1}{8}$ in. If the lathe spindle turns one-half as fast as the leading screw, it follows that the leading screw revolves twice while the work turns once. In this case, the result is that on the finished work the distance between any two threads will be twice as great as the length between two threads on the leading screw; this means that, with a leading screw of two threads per inch, the pitch of the resultant screw will be 1 in., and there will be one thread per inch of length.

It is obvious that there must be means of causing the lathe spindle to revolve faster or slower than the leading screw. The speed depends upon the screw to be cut—that is, on whether it has a greater or less number of threads per inch than the leading screw. The variations in speed are obtained by placing a number of gears, known as change gears, on the lathe spindle and the leading screw, the gears meshing with each other. When there is only one change of speed between the lathe spindle (or in some lathes, the stud) and the leading screw, the series of gears is called a simple train; but when there is more than one change of speed, the train is called compound. It is usual to employ a compound train when the numbers representing the ratio of the leading screw and of the screw to be cut extend beyond the limits of an ordinary, or standard, series of change wheels, which consists, as previously stated, of twenty-two wheels.

Before the change wheels for any particular job can be found, it is necessary to determine the ratio between the lead of the screw to be cut and the lead of the leading

screw. Write them down thus:

$$\frac{\text{Lead of screw to be cut}}{\text{Lead of leading screw}} = \frac{\text{drivers}}{\text{driven}}$$

Or, if desired, the ratio may be expressed thus:

$$\frac{\text{Threads per inch of the leading screw}}{\text{Threads per inch of required screw}} = \frac{\text{drivers}}{\text{driven}}$$

But remember that, whichever method is used, the numerator and the denominator must be expressed in the same manner. When lead is used for the numerator, lead must be used for the denominator; and when threads per inch are used for the numerator, threads per inch must be used for the denominator. The following examples make the matter plain: The number of threads per inch of the leading screw is assumed to be 2, and the pitch $\frac{1}{2}$ in.

(1) Find the ratio for a screw of $\frac{5}{8}$-in. lead.

$$\text{Ratio} = \frac{\frac{5}{8}}{\frac{1}{2}} = \frac{5}{8} \times \frac{2}{1} = \frac{10}{8} = \frac{5}{4}$$

(2) Find the ratio for a screw of $1\frac{1}{4}$-in. lead.

$$\text{Ratio} = \frac{1\frac{1}{4}}{\frac{1}{2}} = \frac{\frac{5}{4}}{\frac{1}{2}} = \frac{5}{4} \times \frac{2}{1} = \frac{10}{4} = \frac{5}{2}$$

(3) Find the ratio for a screw of $\frac{1}{4}$-in. lead.

$$\text{Ratio} = \frac{\frac{1}{4}}{\frac{1}{2}} = \frac{1}{4} \times \frac{2}{1} = \frac{2}{4} = \frac{1}{2}$$

(4) Find the ratio for a screw of $2\frac{1}{2}$-in. lead.

$$\text{Ratio} = \frac{2\frac{1}{2}}{\frac{1}{2}} = \frac{\frac{5}{2}}{\frac{1}{2}} = \frac{5}{2} \times \frac{2}{1} = \frac{10}{2} = \frac{5}{1}$$

If the number of threads per inch of the required screw is given, it should be converted into lead or worked out as follows:

(5) Find the ratio for a screw having fourteen threads

per inch, the leading screw having two threads per inch. Ratio $= \frac{2}{14} = \frac{1}{7}$.

**Calculating Simple Trains of Change Gears.**—In the following examples of working out change gears, unless otherwise stated, the leading screw has two threads per inch, or $\frac{1}{2}$-in. pitch, this being the standard leading screw for British lathes.

It is desired to cut a screw having five threads per inch. Form a fraction whose numerator shall be the number of threads per inch on the leading screw, and whose denominator shall be the number of threads per inch required to be cut. Following this rule, the fraction $\frac{2}{5}$ is obtained. Multiplying both terms of this fraction by 10, $\frac{2 \times 10}{5 \times 10} = \frac{20}{50}$ is obtained, these being the necessary change wheels.

As already explained, the pitch or lead of the screw can be substituted for the number of threads per inch. Thus it is desired to cut a thread of $\frac{3}{8}$-in. pitch. To find the ratio, $\frac{\frac{3}{8}}{\frac{1}{2}} = \frac{3}{8} \times \frac{2}{1} = \frac{6}{8} = \frac{3}{4}$. Multiplying both terms of this fraction by 15, $\frac{3}{4} \times \frac{15}{15} = \frac{45}{60}$, the 45 gear being the driver, and the 60 gear the driven.

Again, it is desired to cut a thread having six threads per inch. The ratio is $\frac{2}{6}$, and multiplying both terms of this fraction by 10, $\frac{2}{6} \times \frac{10}{10} = \frac{20}{60}$, which are the necessary change wheels.

In the foregoing examples, which are for simple trains, the distance between the driver and the driven gear may be made up by two even intermediate gears or any single

wheel that will properly mesh. Here it may be mentioned that, having found the ratio, note should be taken whether the screw to be cut is to have a left- or right-handed thread, and whether it is finer or coarser than the pitch of the leading screw. If the required screw is to have a right-hand thread, the leading screw, which is always right-handed, must revolve in the same direction as the work. This means that the cut is taken in the direction from the tailstock to the headstock. When a left-hand thread is wanted, the leading screw must turn in the opposite direction to the work, and in this case the cut is taken from the headstock to the tailstock. The tumbler wheels which are fitted at the back end of the headstock enable the leading screw to be reversed by the simple movement of a lever.

**Calculating Compound Trains of Change Wheels.**—Compound trains are generally used for cutting screws with more than twelve threads per inch and for screws having a lead of more than $1\frac{1}{8}$ in. Suppose that a required screw is to have twenty-four threads per inch, the ratio is $\frac{2}{24}$; and consequently, if a single train were used, the wheel on the lathe spindle would have to revolve twelve times to one turn of the leading screw. To do this, a 240-wheel would have to be fixed on the lathe spindle, and a 20-tooth gear on the leading screw. This is an impossible drive; and apart from this, the set of change wheels does not include a wheel having 240 teeth. To find the necessary gears, then, proceed as follows: $\frac{20}{240} = \frac{2}{6} \times \frac{10}{40}$. Multiplying both terms of the first fraction by 10, $\frac{2}{6} \times \frac{10}{10}$, $\frac{20}{60}$ is obtained; and multiplying both

terms of the second fraction by 3, $\frac{10}{40} \times \frac{3}{3}$, $\frac{30}{120}$ is obtained. The change gears are therefore: $\frac{\text{drivers } 20 \times 30}{\text{driven } 60 \times 120}$. The 20 gear is the first driving wheel, the 60 wheel is a driven wheel on the quadrant stud, the 30 wheel is a driver wheel on the quadrant stud, and the 120 wheel is fixed on the lead screw.

Committing to memory the rule first given and now repeated, no difficulty arises in working out any combination of change wheels:

$$\frac{\text{Lead of screw to be cut}}{\text{Lead of leading screw}} = \frac{\text{drivers}}{\text{driven}}$$

It is desired to cut a screw having twenty-seven threads per inch on an American lathe with a lead screw having six threads per inch. The change wheels being arranged in multiples of 4, the ratio is $\frac{6}{27} = \frac{2}{9} = \frac{2 \times 1}{3 \times 3}$. Multiplying both terms of the first fraction by 12, $\frac{2 \times 12}{3 \times 12}$, $\frac{24}{36}$ is obtained; these are the first driver and first driven gears. Multiplying both terms of the second fraction by 20, $\frac{1 \times 20}{3 \times 20}$, $\frac{20}{60}$ are the remaining gears. The 24 gear is placed on the mandrel, and is the driver; the 36 gear is placed on the quadrant stud, and is driven by the 24 gear; and the 20 gear is fitted on the quadrant stud, and drives the 60 gear, which is fixed on the leading screw.

**Proving Change-wheel Calculations.** — In order to avoid errors, it is good practice to prove, in one of two ways, the correctness of the change-wheel calculations.

(1) $\frac{\text{Driver gears multiplied together}}{\text{Driven gears multiplied together}} \times$ lead or pitch of leading screw = lead of screw to be cut.

(2) $\frac{\text{Driven gears multiplied together}}{\text{Driver gears multiplied together}} \times$ number of threads per inch of leading screw = number of threads to be cut.

Taking, for example, the change gears worked out for cutting twenty-four threads per inch, $\frac{\text{driven gears}}{\text{driver gears}} = \frac{60 \times 120}{20 \times 30} = 12$, and $12 \times 2 = 24 =$ number of threads to be cut. Taking the change-wheels given for cutting a thread having a pitch of $\frac{3}{8}$ in., $\frac{\text{driver}}{\text{driven}} = \frac{45}{60} = \frac{3}{4}$ and $\frac{3}{4} \times \frac{1}{2} = \frac{3}{8}$ in. lead.

To prove the correctness of the change gears given for cutting twenty-seven threads per inch on an American lathe having a lead screw with six threads per inch, $\frac{\text{driven gears}}{\text{driver gears}} = \frac{36}{24} \times \frac{60}{20} = \frac{9}{2}, \frac{9}{2} \times \frac{6}{1} = \frac{54}{2} = 27$ threads per inch.

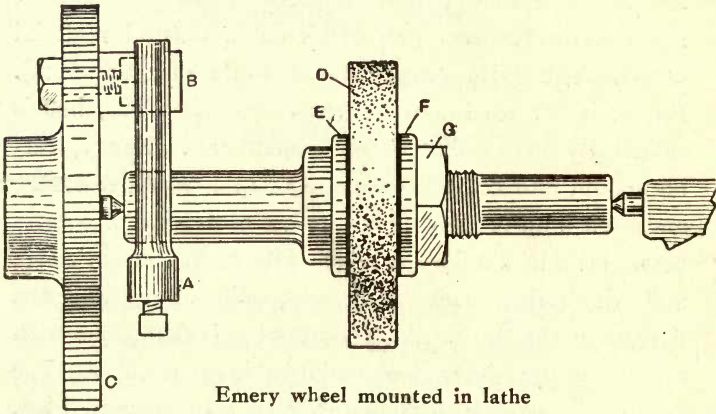
**Cutting Double, Triple, and Quadruple Threads.**—In the cutting of a double thread, first one thread is cut in the usual manner until the uncut material between the grooves is equal to the width of the thread already cut. The change gears are then disengaged, and the lathe spindle, along with the work, is given half a turn. The gears are then intermeshed, and the second thread cut. When cutting triple threads, the work is given a third

of a revolution, and in the case of quadruple threads, a quarter of a revolution.

**Emery Wheels, Carborundum Wheels, etc.**—Abrasive materials made up into wheels and discs include emery, a natural product; corundum, also a natural product, consists of aluminium oxide, which, combined with protoxide of iron, gives emery; carborundum, which is carbide of silicon, produced at a high temperature in the electric furnace; and alundum, another product of the electric furnace, prepared from a natural material known as bauxite (amorphous hydrate of aluminium). Emery is the least hard of these four abrasives, but is sufficiently hard to serve for general use. Emery, carborundum and other wheels are of at least three kinds, and each kind is made in a number of degrees of coarseness. (1) The abrasive is mixed with clay, shaped, dried, and kiln-burnt. This is a non-elastic wheel, and the hardest of the three. (2) The abrasive is dampened with sodium silicate (water glass) and dried in an oven. (3) The abrasive is mixed with shellac solution, moulded and dried. This is an elastic wheel, and is the softest.

Grinding machines are manufactured in a variety of styles, their essential being a strong spindle, to carry the wheel, capable of being rotated at a high speed. A lathe is sometimes adapted for the purpose as illustrated on p. 98. A is a dog or carrier attached to the shaped and threaded arbor or spindle supported between centres, B the driving plate, C the faceplate, D the grinding wheel, E and F washers with felt between them and the grinding wheel, and G the tightening nut.

**Truing Emery and Carborundum Wheels.**—When solid emery or carborundum wheels are glazed on their surface they will not grind, and require dressing before any satisfactory work can be got from them. The best method of dressing emery wheels is to use a diamond which is mounted in a steel holder and moved across the face of the emery wheel while it is revolving. Some of these diamond turning or dressing tools are simply held in the




Emery wheel mounted in lathe

hand while being used, and others are held in the grinding machine and moved across the face of the stone in a similar manner to a tool mounted in a lathe slide-rest.

Diamonds for dressing emery wheels cost from £2 to £60 each, and they easily get broken or torn from their mountings. They are generally placed in a small hole in the end of the steel bar, and molten brass or copper poured round them. Then the brass or copper is slightly hammered all round the diamond in order to hold it tight. Often the diamond works itself loose and falls out, and it is

then difficult to find, owing to the fact that the diamonds used for dressing emery wheels are mostly black, or what are known as "carbon" or "bort" diamonds.

Useful tools for trimming up and dressing the surfaces of emery wheels consist of revolving discs of hard steel contained in suitable holders. As soon as the discs come into contact with the surface of the wheel, they quickly acquire the same circumferential speed as the wheel, and, owing to their skewed or oblique setting, their sharp edges move rapidly to and fro, thus quickly removing the inequalities and leaving a perfectly true surface on the emery wheel. The thin discs always retain their sharp cutting edges, which, being continuous, produce an even surface. They wear very slowly, and when worn out are easily replaced.

**Annealing Steel and Iron.** — The stresses produced in forging steel are eliminated by annealing, in which process the steel is raised to a low red heat, this heat maintained for some time, and the steel then allowed to cool slowly. Highly heated steel rapidly oxidises in contact with the air; and steel so affected will show hard and soft places after the subsequent hardening process. For this reason, steel to be annealed is commonly packed in boxes from which the air is excluded. The use of charcoal packing further assists this object, and helps to remove the scale or black skin and impart a metallic surface. The ordinary method of annealing steel is to heat it to a bright red and pack in any good non-conductor of heat, such as soft-coal soot, fine dry lime or ashes, and allow it to cool very slowly, the slower the better. The risk of over-

heating must always be guarded against. A good plan is to put the work into a box made for the purpose, filling the box with charcoal dust, and plugging up the ends so that the air is kept from the work, then to put the box and its contents into the fire and keep them there until they are heated thoroughly and the steel is at a low red heat; the work is then taken from the fire and allowed to remain in the box until cold. The steel should prove clean and soft, and without bright spots ("pins"), which impede the filling and working. A good packing material for use in annealing is the spent bone-black from case-hardening boxes. It can be used over and over again, adding each time a small quantity of fresh waste bone-black.

**Hardening Steel.**—When tool steel is "quenched" (suddenly cooled) from a certain heat, which varies with the quality of the steel, it becomes hard and brittle, having greater tensile strength, but less durability. The change in the condition of the steel occurs during a comparatively short range of temperature—the "critical temperature"—and the more rapidly the cooling takes place through that particular range the harder will the steel be. It matters but little how rapid the cooling is either down to or beyond the critical range; it is the rapid cooling through the critical range that is really important. The critical temperature is known as the "point of recalescence," and varies with the temper or carbon content of the steel. It is in the neighbourhood of 1288° to 1292° F. (670° to 700° C.). It is now recognised that the point of recalescence indicates the proper quenching temperature. At this point

the steel loses its magnetic properties, and can neither attract other pieces of steel nor be attracted by them. A tool held on a magnet and then heated will automatically fall off into the quenching bath at the proper moment.

The quenching of steel at the lowest temperature at which it will harden produces the strongest and toughest tool, whereas when the tool is heated to the highest point of the critical range and then suddenly quenched, the maximum hardness and brittleness are produced.

Steel forgings do not pass direct from smithy to the hardening shop. Black, hot-finished forgings are covered with a skin or film or iron oxide which is incapable of being hardened, and must therefore be ground off, for which purpose a wet stone should be used, and not an emery wheel, carborundum wheel, etc. The object of the last precaution is to avoid glazing the steel, because, inasmuch as glazing is really a burning of the carbon, the glazed spots are left in a condition incapable of being hardened by heat treatment. Both forgings and work that has been shaped with cutting tools need to be very carefully examined before hardening. Sharp angles, deep scratches, etc., are extremely likely to develop into cracks during hardening.

In the blacksmith's shop the most usual method of heating steel for hardening is in the smith's fire made with coke. Larger articles may be packed in an iron box or tube which may then be heated in a furnace. Small tools may be sufficiently heated by laying them on the glowing mass of a much larger tool. The gas blow-pipe and the alcohol blow-lamp are also of use at times. A modern

method of heating pieces of intricate shape is an enclosed bath of molten chemical salts, the temperature of which can be noted to a nicety. Another and more usual method is to employ high-power gas or oil furnaces. Electrically heated muffles are also available for small tools; and tools may even be heated by making them an actual part of an electrical circuit. Ordinarily, any common source of heat will serve the purpose, as carbon steel is rarely heated above cherry red; but there is an advantage in so heating a tool that the access of air to it is prevented. When heating work in the forge fire every care should be taken to prevent the air blast from the tuyère affecting the carbon in the surface of the steel, and with this object the work should be protected with a good thickness of incandescent fuel. Coke fuel is preferred to coal because it contains less sulphur; but the best fuel of all is charcoal, which does not contain any sulphur at all. Access of air to red-hot steel always involves the risk of burning the surface carbon; but the risk is reduced to a minimum when the steel is heated in a charcoal fire contained in a muffle furnace. With the same object, small work may be heated in a tube closed at one end, and, in the case of round articles, kept constantly turning.

The steel having been heated must next be quenched, and no time should be lost between the two operations. The customary method of quenching steel is to plunge it in a bath of liquid, such as water, oil, brine, mercury, molten lead, etc. Metallic liquids, such as mercury and molten lead, notably the former, are particularly good quenching mediums, because they are, relatively to water,

excellent heat conductors, and consequently quickly rob the work of its heat. An ice-cold quenching medium is not required, because, as already pointed out, the actual change in the condition of the steel takes place while it is passing through the critical range of temperature, far above the temperature at which lead becomes liquid.

TABLE OF TEMPERATURES FOR HARDENING.

| *Approx. temperature °F.* | *Colour in full daylight* | *Approx. temperature °C.* |
|---|---|---|
| 430 | Pale yellow | 221 |
| 450 | Straw | 232 |
| 470 | Dark straw | 243 |
| 500 | Brown-yellow | 260 |
| 530 | Light purple | 277 |
| 550 | Purple-blue | 288 |
| 560 | Full blue | 293 |
| 580 | Polish blue | 304 |
| 600 | Dark blue | 316 |
| 750 | Bright red (in the dark) | 400 |
| 880 | Red (in twilight) | 470 |
| 980 | Nascent red | 530 |
| 1,080 | Red | 580 |
| 1,290 | Dark red | 700 |
| 1,470 | Nascent cherry | 800 |
| 1,660 | Cherry | 900 |
| 1,830 | Bright cherry | 1,000 |
| 2,010 | Dull orange | 1,100 |
| 2,100 | Light orange | 1,150 |
| 2,190 | Lemon | 1,200 |
| 2,280 | Light straw | 1,250 |
| 2,400 | White | 1,320 |
| 2,550 | Brilliant white | 1,400 |
| 2,730 | Dazzling white | 1,500 |

NOTE.—Above the temperature of 600° F., the Centigrade equivalent is given to the nearest ten.

Thus it follows that boiling oil and molten lead are occasionally used as quenching baths. An ice-cold bath is far too cold, and is to be avoided. The method of quenching, apart from the nature of the cooling bath, is of great importance. The chief aim is to achieve uniform cooling. A small article is dipped bodily into the bath—not slowly, but in such a way that the whole of it is subjected to the cooling effect at the same instant. Any breach of this rule will cause distortion. Articles that are too large to be wholly immersed are sprayed, and to do this efficiently a good and steady water supply is essential. The water jet, too, is available for articles as small as hammers when it is wished to harden the faces alone. Steel is tested for hardness by means of a file.

**Tempering.**—The object of tempering is to reduce the degree of brittleness brought about by the process of hardening. Unfortunately, the hardness suffers, too, in the course of tempering, but a compromise between extreme hardness and brittleness on the one hand and extreme softness and toughness on the other is sought. In tempering, the steel is heated to a moderate temperature, the degree of which chiefly determines the result, the method of cooling—whether by allowing it to cool in air or by quenching in cold water—making no difference. The lower the temperature to which the steel is heated in tempering, the less will the hardness suffer. The correct temperature is indicated by the colour tint assumed by the film of oxide upon the surface of the work, as in the following list:

*Yellow.*—Scrapers for brass; steel engraving tools;

scribers, burnishers, light turning tools; planing tools for steel; hammer faces; planing tools for iron; ivory-cutting tools.

*Straw Yellow.*—Circular cutters for metal; paper-cutting knives; shear blades in general; wood-engraving tools; boring cutters; bone-cutting tools; screwing dies; taps.

*Brown Yellow.*—Leather-cutting dies; chasing tools; inserted saw teeth; reamers.

*Light Purple.*—Rock drills; brace bits; penknives; stone-cutting tools; twist drills; moulding and planing cutters for hard wood; dies and punches; gouges; cup tools; snaps; plane irons.

*Dark Purple.*—Circular saws for cold metal; flat drills for brass; wood borers; drifts; coopers' tools; augers; circular cutters for wood; dental and surgical instruments; cold setts and hand chisels for steel and cast iron; axes and adzes; gimlets.

*Pale Blue.*—Cold setts for wrought iron; saws for bone and ivory; firmer chisels; needles; moulding and planing cutters for soft wood.

*Blue.*—Hack saws; screw drivers; saws for wood; springs in general.

The colours will not be seen properly on a dirty piece of steel that probably already bears a film of oxide. Before heating, brighten the steel with a piece of hard stone, or possibly with fine emery cloth, and the colours will then be easily seen. The tints are very deceptive by artificial light, and it is best to do the work in daylight. Do not attempt to temper a small tool in an ordinary

gas flame, because the soot and deposits will prevent a proper estimation of the oxide tint being formed. For various reasons it may be difficult to judge of the temperature of a large piece by means of the tint. When this is the case, lay upon it a small piece of brightened sheet steel, using the colour of this as an index to the temperature of the article.

Molten lead or lead-tin alloy is a convenient medium for tempering steel articles of unequal thickness, as these can then be heated more uniformly than in an open fire or on an iron plate over a fire. Lead melts uniformly at a temperature of 612° F. (322° C.), and by alloying the lead with tin in varying proportions, ranging from 7 parts of lead and 4 of tin to 25 of lead and 1 of tin, an extensive range of temperatures may be conveniently obtained. The surface of the molten lead is covered with powdered charcoal to prevent oxidation and consequent waste of metal. Boiling linseed oil can be used for heating articles of which the temper needs to be drawn at a temperature of about 600° F. (315° C.), corresponding to a dark blue tint. Emery powder and sand are other convenient mediums for heating delicate parts.

Some tools require to be tempered to an even colour throughout, and these may be laid upon an iron plate over a bright fire and rolled over as they heat to ensure evenness ; or they may be held by one end in a clean Bunsen flame or a spirit-lamp flame, and moved about, changing ends and " leading the colour " along until even. Another method is to heat an iron plate to redness in the forge, carry it to the light, and place the tool upon it until the

correct colour appears. A tap or a reamer may be thus tempered evenly from end to end, and then the temper of the handle end may be further let down to a blue, allowing the blue to run up to the commencement of the cutting edges, where it will fade off through red into the straw colour: this gives the handle end greater spring and toughness.

Gas-heated hot-plates for use in tempering are to be found in many works.

Tempering in molten tallow has been found a convenient method. The gas-heated tallow pot is kept at a constant temperature, which is regulated to suit the kind of tools. Articles to be tempered are hung in the tallow or stirred in it until of uniform temperature, and are then laid aside to drip and cool, after which they may be washed in hot soda water.

A variety of gas-heated oil tempering furnaces are available. In these a bath of oil or tallow in which the steel is immersed is heated until a thermometer indicates that the correct temperature has been attained. Small work is suspended in the oil bath by means of wire baskets. Naturally, the boiling point of the oil limits the maximum temperature obtainable, and this is in the neighbourhood of 600° F. (about 315° C.).

**Heat-treatment of High-speed Steel.** — When high-speed steel was first introduced into industry it was thought only suitable for tools that could be forged into shape. However, it was soon found that by carefully annealing this class of steel could easily be machined. The process of annealing is of great importance, and is best

performed in specially designed sealed furnaces, known as muffles. In the furnaces the steel is surrounded by a fireclay jacket, and the required heat is obtained uniformly by radiation, as no part of the flame touches the steel, the heat having to pass through the fireclay muffle or jacket. It thus follows that a more uniform heating is possible. In addition to softening the steel and rendering it easy to cut, annealing has the effect of bringing the steel into a more uniform and homogeneous molecular condition by eliminating any internal strains that may have set up in the manufacturing operations, so that when the finished tool is heated, preparatory to hardening, equal expansion follows, and equal contraction during cooling.

When hardening high-speed steel, the cutting portion only should be gradually and carefully brought to a yellow heat, and then rapidly raised to a white welding heat; the melting of the nose of the tool ensures that the right temperature has been reached, and therefore is rather an advantage than otherwise. The tool should now be withdrawn from the fire, and, without losing any time, cooled by being placed in a blast of cold air, the stronger the better. Another efficient method of treatment is to raise the nose of the tool to a white heat, carefully following the instructions already given, and then to lower the temperature to a bright red heat (say 1,700° F. or 927° C.) either by air blast or in the open air, and finally to quench in a bath of whale or rape oil.

**Case-hardening.**—Case-hardening is a process whereby carbon is added to the outer skin of wrought-iron and the softer steels. Owing to the small percentage of carbon

that is present in low-carbon ("mild") steel, it is not possible to harden it right through; hence a process for hardening the outer surface is desirable. Case-hardening adds a considerable amount of carbon to the steel, and thus practically converts the outer layer, or skin, into tool steel. The pieces requiring treatment are generally placed in a furnace and heated to a certain temperature, which will vary according to the steel and the composition used for hardening. Various case-hardening compounds are obtainable, these including bone, charcoal, charred leather, etc., but the easiest method of obtaining reliable results is to use special case-hardening composition as sold. The depth to which the carbon penetrates depends upon the hardening composition used, the length of time the metal is in the furnace, and the temperature to which the article is heated. When using charcoal, bone, or special composition, the articles are packed in a wrought-iron or cast-iron box into which has first been placed some compound, and are then covered with the compound. The lid is then put into the mouth of the box and sealed or luted with clay in order to prevent the escape of the gases that will be generated. The box is then placed in the furnace and heated until the exterior is of a bright orange or nascent yellow colour, this being necessary in order to allow the heat to penetrate to the interior of the box. Care should be taken that the heating up is done rapidly, and that the correct temperature, once attained, should be kept up without interruption. After the box has been in the furnace for about three hours the hardened layer will probably be about $\frac{1}{32}$ in. deep; greater depths can

be obtained by longer heating. Immediately the box is taken from the furnace the contents should be dropped into water, this completing the process. If the articles were dropped into oil they would be much tougher than, but not so hard as, if dropped into water, owing to the slightly retarded cooling when passing through the critical range.

If it is desired to know the thickness of the hardened exterior, test pieces of similar metal should be placed in the box; these can be broken after cooling and the thickness noted. It is usual, when only portions of the article require hardening, to pack fireclay tightly over the part that is to be left soft. Another method sometimes adopted for small arlticles is to plate by means of copper or nickel the portions that do not require hardening; the carbon will not penetrate this coating, and thus the metal retains its original softness. Specialists in case-hardening disagree on one particular point of procedure—whether to quench the work straight from the boxes, or whether to allow to cool, reheat in muffles, and then quench.

The old and simple way of case-hardening by means of potassium prussiate is not to be recommended for general use, as in this process the hardness is confined to the surface only, and is not of sufficient depth to withstand wear. The work is heated to a bright red, and then covered with the powdered potassium prussiate. The hot iron will fuse the powder, a covering of which will adhere. The work is again heated to redness, and again covered with the powder. These operations may be repeated several times, or only once, according to the depth of hardness

required. The hardening is finally effected by heating the iron to a bright red and immediately plunging it into cold water.

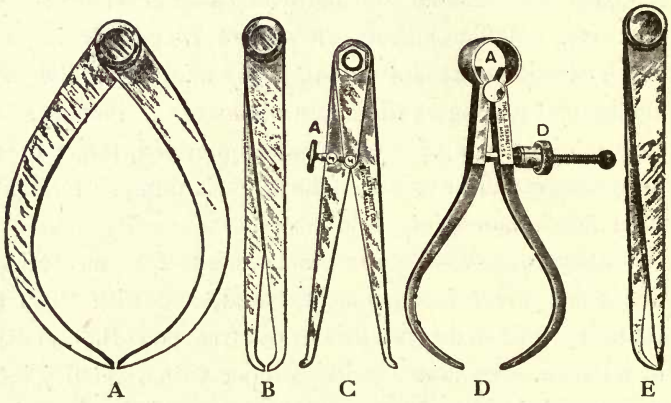
Immersion in a bath of molten potassium cyanide is a method of case-hardening and also of colouring suitable for work that requires only a very thin film of hard material. In a typical gas-heated cyanide furnace, the cyanide is brought from the cold to a hardening heat in about forty minutes, and the extreme depth of case-hardening is obtained in from seventeen to twenty minutes, prolonged heating not adding to the depth of the case. Small parts are contained in a wire basket and immersed, larger ones being suspended on wires. The work is dumped straight from the furnance into cold water.

**Callipers.** — These are tools used for measuring diameters, either internal or external, and with them a skilled person can detect a difference of, say, one-thousandth of an inch. A shows outside calliper with riveted joint, and B an inside calliper of the same kind. Superior callipers may have bolted joints, the nut being adjusted to make them tighter or looser as desired.

In using a pair of callipers great care must be taken to hold them correctly. The points should be exactly opposite each other, and nicely rounded off with an oilstone in order that there are no sharp edges. The edges of the points should also be exactly parallel with each other, otherwise errors in measurement will take place, especially when they are being set to a dimension on a rule. Thus, if the points are not exactly parallel with each other and the callipers are set to, say, 4 in. (using the widest end of

the points), and work is turned to them, the result will be that the bar is under size. Now if the callipers are set to the nearest edges of the points, the bar will be the correct size.

In measuring external diameters the callipers should be held with just sufficient force to prevent their falling, and it ought to be possible for them to fall over the work




A and B.—Outside and inside callipers. C.—Screw-adjusting callipers. D.—American callipers. E.—Hermaphrodite callipers or "moffs."

by their own weight. In measuring internal surfaces, great care is necessary, more so even than for external surfaces. The points should be narrow and curved on the measuring surfaces. It should be possible to move the callipers sidewise to a very small degree in measuring holes. The correct use of callipers requires much practice.

Of the many other kinds of callipers in use, C illustrates the firm-jointed screw-adjusting callipers; the screw A is attached to the short auxiliary leg by means of a nut.

This tool can be closed or opened to a size near the required dimension, and then adjusted by means of the thumbscrew. The American inside and outside callipers are easily manipulated. They are fitted, as in D, with a spring, A, the pressure from which constantly keeps them open, and they are prevented from opening too far by the round split-nut D. It is not necessary to turn the nut round in order to open the callipers, as by pressing on the milled head with a finger and thumb the two halves open at the end nearest the leg, and permit the nut to be moved instantaneously to an approximate position. The pressure from the spring causes the nut to grip the thread tightly.

The hermaphrodite (also called "odd legs," "jenny,"- and "moffs") calliper, shown at E, is used for marking lines parallel with an edge, or for marking out the centre of a round or square bar. A better form is provided with an adjustable scriber leg.

**Micrometers.**—When accurate dimensions are required in the working of metals, more delicate instruments than rules, callipers, etc., must be employed. The ordinary form of micrometer, for measuring from 0 in. to 1 in. by thousandths, is shown at A (p. 117). It has a locking ring A, which is given half a turn to prevent the moving of the spindle when measuring articles of the same size. The measurements are made in the gap B, between the end of spindle C and the anvil D. To prevent injury to the instrument when in use, and also to enable similar dimensions to be obtained by several persons, a ratchet stop A is fitted to many micrometers, as shown in diagram B.

The spindle B is screwed forwards by revolving the ratchet by means of the finger and thumb, and immediately the spindle touches the article being measured the ratchet slips, and does not allow the spindle to be strained. Another advantage is that the spindle can be screwed in or out more rapidly by turning the ratchet stop A than by turning the barrel. For instance, the spindle may perhaps make one revolution each time the thumb and finger is moved; this would not be so with the barrel C.

The instrument shown at C is used for measuring large diameters, the screw only having a movement of 1 in. Standard length bars A are provided in order that the accuracy of the instrument may be tested. When the micrometer is provided with a finger ring (*see* D), it can be held in one hand.

The inside micrometer shown at E is similar in construction to an external micrometer, the difference being the measuring points A and B. A disadvantage of this design of instrument is that small holes cannot be measured, owing to the thickness of the points.

**How to Read a Micrometer.** — In the micrometer shown at F, the spindle A is attached to the thimble B at the point C, and the part of the spindle which is concealed within the sleeve is threaded to fit a nut in the frame D. The frame being held stationary, the thimble B is revolved by the thumb and finger, and the spindle being attached to the thimble revolves with it, and moves through the nut in the frame, approaching or receding from the anvil E according to the direction of rotation.

The article to be measured is placed between the anvil

E and the spindle A, and the measurement of the opening between the anvil and the spindle is shown by the lines and figures on the sleeve D and the thimble B.

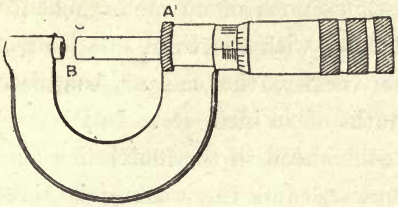
The pitch of the screw threads on the concealed part of the spindle is 40 to 1 in.; therefore one complete revolution of the spindle moves it longitudinally one-fortieth (or twenty-five thousandths) of an inch. The sleeve D is marked with forty lines to the inch, corresponding to the number of threads on the spindle. When the micrometer is closed the bevelled edge of the thimble coincides with the line which is marked 0 on the sleeve, and the zero line on the thimble agrees with the horizontal line on the sleeve.

Open the micrometer by revolving the thimble one full revolution, or until the 0 line on the thimble again coincides with the horizontal line on the sleeve. The distance between the anvil E and the spindle A is then $\frac{1}{40}$ in., or ·025 in., and the bevelled edge of the thimble will coincide with the second vertical line on the sleeve. Each of these lines indicates a distance of $\frac{1}{40}$ in. Every fourth line is made longer than the others, and is numbered 0, 1, 2, 3, etc., each indicating a distance of $\frac{1}{10}$ in. The bevelled edge of the thimble is marked in twenty-five divisions, and the fifth lines are numbered 5, 10, 15, 20 and 0. Rotating the thimble from one small mark to the next moves the spindle longitudinally $\frac{1}{25}$ of $\frac{1}{40}$ in., that is, one-thousandth of an inch; rotating it two divisions indicates two-thousandths, etc. Rotating from zero to zero, through 25 divisions, makes a complete revolution, which is ·025 in. or $\frac{1}{40}$ in.

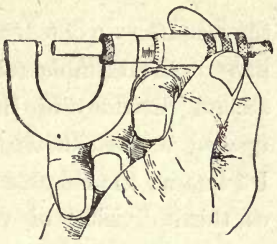
To read the micrometer, multiply the number of vertical divisions visible on the sleeve by 25, and add the number of divisions on the bevel of the thimble from 0 to the line which coincides with the horizontal line on the sleeve. For example, as the instrument is shown at A, seven divisions are supposed to be visible on the sleeve. Multiply this number (7) by 25, and add 3, the number of divisions shown on the bevel of the thimble. The micrometer is open to one hundred and seventy-eight thousandths ($7 \times 25 = 175 + 3 = \cdot 178$).

Readings in ten-thousandths of an inch are obtained by means of a vernier (so called from the name of its inventor) or series of divisions on the barrel A, as shown in Diagram G. These divisions are ten in number, and occupy the same space as nine divisions on the thimble B; for convenience in reading, they are figured 1, 2, 3, 4, 5, 6, 7, 8, 9, 0. The "0" is zero and "10." When a line on the thimble coincides with the first line of the vernier, the next two lines to the right differ from each other one-tenth of the length of a division on the thimble; the next lines differ by two-tenths, etc. The graduations on the barrel and the thimble are shown enlarged at H.

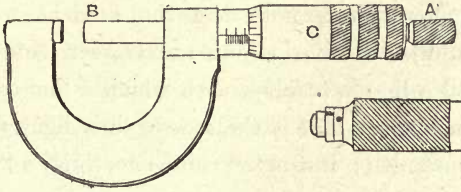
When the micrometer is opened the thimble is turned to the left; and when a division passes a fixed point on the barrel it shows the micrometer has been opened one-thousandth of an inch. Hence, when the thimble is turned so that a line on the thimble coincides with the second line (end of the first division) of the vernier, the thimble has moved one-tenth of the length of one of its divisions, and the micrometer opened one-tenth of one-



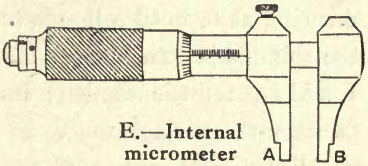

A.—Ordinary micrometer



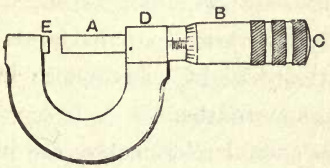
D.—Micrometer with finger ring



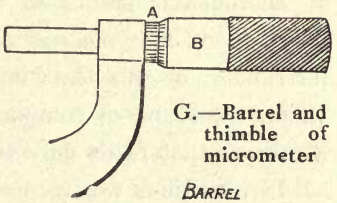

B.—Micrometer with ratchet stop



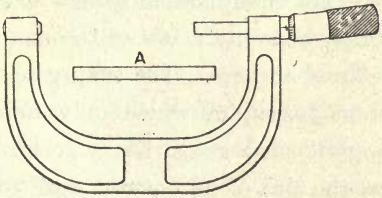

E.—Internal micrometer



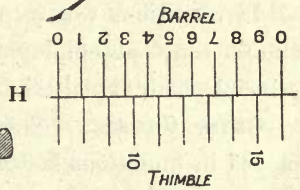

F.—Micrometer set for ·178 in.

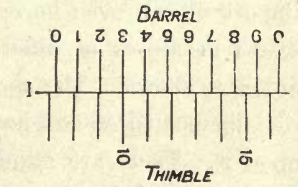



G.—Barrel and thimble of micrometer




C.—Micrometer for large diameters




H and I.—Thimble and barrel graduations

thousandth, or one ten-thousandth of an inch. When a line on the thimble coincides with the third line (end of second division) of the vernier, the calliper has been opened two ten-thousandths of an inch, etc. In Diagram I a line on the thimble coincides with the fourth line (end of third division of vernier), and the reading is three ten-thousandths of an inch.

To read the micrometer, note the thousandths as usual, then the number of divisions on the vernier, commencing at 0, until a line is reached with which a line on the thimble is coincident. If it is the second line, figured 1, add one ten-thousandth ; if it is the third line, figured 2, two ten-thousandths, etc.

Micrometers graduated to ten thousandths are used only where fine measurements are required, as in an instrument of this class it is important to avoid wear, which would be of comparatively slight consequence in a calliper that reads only to thousandths.

In munitions works, many special micrometers are in almost constant employment, but they all work on the principle here explained.

**Other Gauges.** — There are many other gauges employed in munitions factories, but only a few of the more important can even be referred to here. The snap gauge exists in scores of different forms, of which only four are here shown. The simplest snap gauge has a general resemblance to A, and has the size of its opening marked upon it. There are minute differences between the sizes of the notches in the opposite ends of the gauge shown at B, one notch representing the required dimension plus

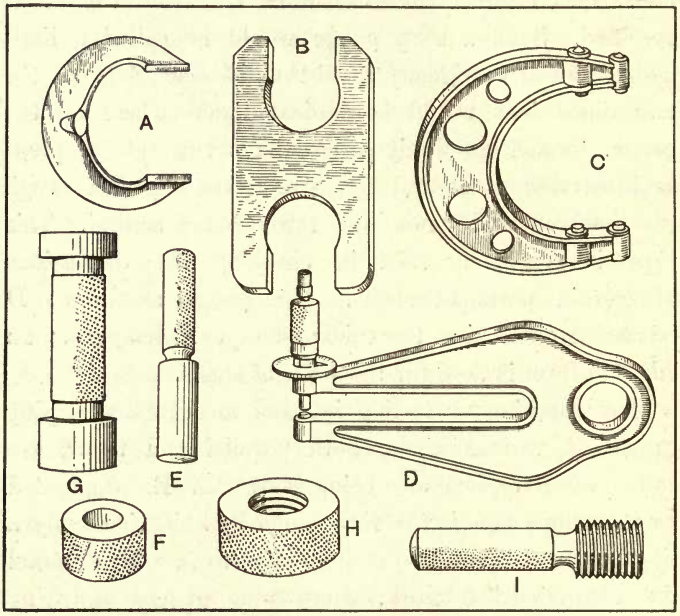
the degree of error permitted on the big side, and the other notch representing the required dimension minus the degree permitted on the small side. This gauge is passed over the work which must "go" into the larger notch, but fail to go—that is, "not go"—into the smaller one. This ensures that the work is within the limits specified. Such a snap gauge would be called a limit gauge, and in very many cases the difference between the two dimensions would be indicated somewhere on the gauge. Sometimes limit gauges have two sets of plugs as illustrated at C, and the work must "go" through the first set, and "not go" through the second. This type is commonly used in checking the dimensions of certain parts of shells. The gauge shown at D is used for checking the thickness of cylinders, etc.; an adapted form is used for the walls of shells.

For checking or testing internal measurements, plug gauges of various kinds, both parallel and taper, are employed, a typical one being shown at E. Suggested by the plug gauge is the ring gauge F, which is simply a ring accurately produced of hard steel to test the external size of cylindrical work. Both plug gauges and ring gauges may be limit gauges, by arranging that, in the case of the plug, one end shall "go" and the other end shall "not go," the gauge then being of the shape shown at G. In the case of the ring gauge, two gauges would need to be employed, into one of which the work would "go," and into the other "not go."

Screw-thread gauges resemble plug and ring gauges, and, in addition, are threaded (*see* H and I).

Squares, bevel protractors, bevel squares, etc., etc., are other well-known gauges. The scribing block is one of the oldest of all gauges, a typical one being shown on p. 49, in use for centring lathe work.

Step gauges are very accurately dimensioned blocks




**Nine Typical Gauges**

of hard steel, each higher step corresponding to a certain higher dimension; such gauges may be made to suit particular requirements.

During recent years great interest has been aroused by the Johansson gauges, which are nothing more or less than rectangular blocks of very hard steel. The distance between any two sides or any two ends agrees with a

dimension clearly stamped upon the surface between those sides or ends, and the remarkable thing is that these blocks are finished to such a degree of accuracy that a number of them may be placed together to measure a length of several inches with a degree of error of only 4 or 5 parts in ten thousand. By means of a full set of the gauges, all dimensions up to 10 in., proceeding by 0·0001 in., can be obtained.

**Wire Gauges.**—Hundreds of different sizes of wire and thicknesses of sheet steel are manufactured, and it is the custom to distinguish them one from another by means of numbers instead of by the dimensions of their diameters or thicknesses (*see* p. 123 for a comparative table of three of them). There is no one gauge or system of numbers universally employed, but in Great Britain the "Standard" (British Imperial Standard) is being more and more adopted, although it must be admitted that many people consider the Whitworth gauge to be a more sensible one. The British Imperial Standard gauge (S.W.G.) is often called the Standard, British Standard, the Imperial Standard, and the English Legal Standard. It was authorised by Act of Parliament on September 4th, 1883, and it came into use on March 1st, 1884. Its gradations extend from 7/0 = ·5 in. to 36 = ·0076 in., there being forty-three numbers.

The Birmingham Wire gauge (B.W.G.) has long been a favourite in England. It is the same as the London or Old English gauge, from numbers 0000 4/0 to 18; from 19 to 36 there are slight differences in the second or third decimal point. It agrees with the ordinary Stubs gauge

for iron, but not with the special Stubs gauge for steel wire.

The American (Brown and Sharpe) wire gauge (B. & S.W.G.) is, of course, but little used in Great Britain. The United States gauge, legalised in 1893, applies to sheet and plate iron and steel. In the S.W.G., B.W.G., B. & S.W.G. etc., the thicker wires (those greater than 0·3 in. in diameter) are designated by a number of ciphers, not exceeding seven or eight. These are sometimes given in full, as, for example, 000000, but more generally the number of ciphers is denoted by a numeral, as, in the example given, 6/0. Strong objections have been urged against the system of denoting various sized wires by gauge numbers instead of by the actual dimensions. The chief objection is the liability to mistake. There is no doubt that it is a more sensible plan to designate the size of a wire by its diameter, thus "diam. 0·5" instead of "S.W.G. 0000000." The former term gives precise information to anybody, whereas the latter does not mean anything to a person unacquainted with the gauge system. This has been recognised by Messrs. Pratt and Whitney, of Hartford, Conn., U.S.A., an American firm whose products are in common use in Great Britain; they make a speciality of the decimal gauge, a notched oval plate gauge patented in June, 1896, and manufactured under licence of the American Society of Mechanical Engineers. In it the sensible system is followed of designating each size of wire by its thickness in decimals of an inch.

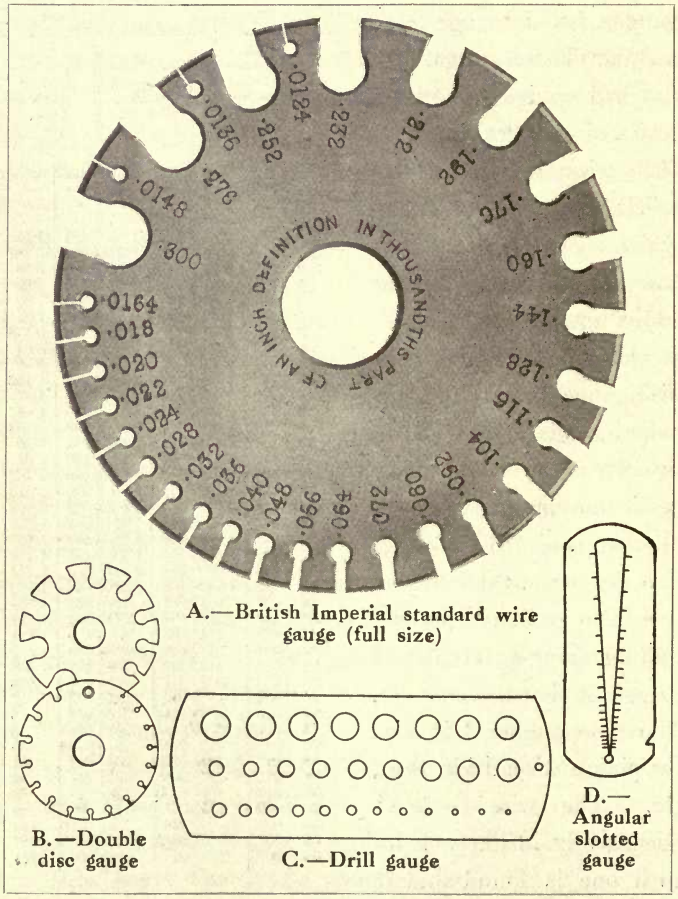
In the Standard wire gauge illustrated by A (p. 124), one side bears the gauge numbers and the other the

corresponding dimensions in decimals of an inch. This illustration shows the gauge as accurately to the actual size as ordinary book-work printing from half-tone blocks allows.

Actual wire gauges are known in at least three types and many different patterns. The types include the notched gauge, holed gauge, and angular slotted gauge. The notched gauge A has a series of notches, in which the wire is successively tried until one is found which it exactly fits. Then the number stamped close to the notch is the "gauge" of the wire. The ordinary disc gauge (known as "circular single") is shown by A, and of its type it is probably the best. Double gauges B are either circular or oval. There are also oblong gauges, folding gauges, combined gauges and callipers, etc. The hole gauge C is used for pinion wire, drills, taps, etc. The wire is tried successively in likely holes until one is found that it

| Number of Gauge. | *British Imperial Standard or English Legal Standard.* | | *American or Brown and Sharpe.* | | *Birmingham or Stubs Iron.* | |
|---|---|---|---|---|---|---|
| | in. | mm. | in. | mm. | in. | mm. |
| 7/0 | ·500 | 12·70 | — | — | — | — |
| 6/0 | ·464 | 11·78 | — | — | — | — |
| 5/0 | ·432 | 10 97 | — | — | — | — |
| 4/0 | ·400 | 10·16 | ·46 | 11·68 | ·454 | 11·53 |
| 3/0 | ·372 | 9·44 | ·409 | 10·388 | ·425 | 10 787 |
| 2/0 | ·348 | 8·83 | ·364 | 9·24 | ·380 | 9·65 |
| 1/0 | ·324 | 8·23 | ·324 | 8·23 | ·340 | 8·63 |
| 1 | ·300 | 7·62 | ·289 | 7·338 | ·300 | 7·62 |
| 2 | ·276 | 7·06 | ·257 | 6·527 | ·284 | 7·21 |
| 3 | ·252 | 6·40 | ·229 | 5·808 | ·259 | 6·578 |
| 4 | ·232 | 5·89 | ·204 | 5·18 | ·238 | 6·04 |
| 5 | ·212 | 5·38 | ·181 | 4·59 | ·220 | 5·58 |
| 6 | ·192 | 4·88 | ·162 | 4·11 | ·203 | 5·156 |
| 7 | ·176 | 4·46 | ·144 | 3·66 | ·180 | 4·57 |
| 8 | ·160 | 4·06 | ·128 | 3·24 | ·165 | 4·187 |
| 9 | ·144 | 3·66 | ·114 | 2·89 | ·148 | 3·753 |
| 10 | ·128 | 3·24 | ·101 | 2·565 | ·134 | 3·40 |
| 11 | ·116 | 2·94 | ·090 | 2·28 | ·120 | 3·04 |
| 12 | ·104 | 2·642 | ·080 | 2·03 | ·109 | 2·768 |
| 13 | ·092 | 2·336 | ·071 | 1·79 | ·095 | 2·413 |
| 14 | ·080 | 2·03 | ·064 | 1·625 | ·083 | 2·108 |
| 15 | ·072 | 1·828 | ·057 | 1·447 | ·072 | 1·828 |
| 16 | ·064 | 1·625 | ·050 | 1·27 | ·065 | 1·65 |
| 17 | ·056 | 1·422 | ·045 | 1·14 | ·058 | 1·473 |
| 18 | ·048 | 1·219 | ·040 | 1·016 | ·049 | 1·244 |
| 19 | ·040 | 1·016 | ·035 | ·889 | ·042 | 1·066 |
| 20 | ·036 | ·914 | ·031 | ·787 | ·035 | ·889 |
| 21 | ·032 | ·812 | 028 | ·711 | 032 | ·812 |
| 22 | ·028 | ·711 | ·025 | ·635 | ·028 | ·711 |
| 23 | ·024 | ·61 | ·022 | ·558 | ·025 | ·635 |
| 24 | ·022 | ·558 | ·020 | ·508 | ·022 | ·558 |
| 25 | 020 | ·508 | ·017 | ·431 | ·020 | ·508 |
| 26 | 018 | ·457 | ·015 | ·381 | ·018 | ·457 |
| 27 | ·016 | ·406 | ·0148 | ·376 | ·016 | ·406 |
| 28 | ·0148 | ·376 | ·012 | ·304 | ·0148 | ·376 |
| 29 | ·0136 | ·345 | ·0116 | ·29 | ·0136 | ·345 |
| 30 | ·012 | 304 | ·010 | ·254 | ·012 | ·304 |
| 31 | ·0116 | ·29 | ·008 | ·203 | 010 | ·254 |
| 32 | 0108 | ·274 | ·0079 | ·199 | 009 | ·228 |
| 33 | ·010 | ·254 | ·007 | ·177 | 008 | ·203 |
| 34 | ·009 | ·228 | 006 | ·152 | ·0076 | ·192 |
| 35 | ·008 | ·203 | ·0056 | ·142 | ·005 | ·127 |
| 36 | ·0076 | ·193 | ·005 | ·127 | ·004 | ·101 |

fits, just as the notched gauge is used. The adjacent number indicates the gauge of the wire. The gauge has a special use in connection with drills. The simplest of all gauges is the angular slotted type, the pocket form being generally made with closed ends as in D, while the




A.—British Imperial standard wire gauge (full size)

B.—Double disc gauge

C.—Drill gauge

D.—Angular slotted gauge

jeweller's gauge has an open end to the angular slot. A slotted gauge is used by passing the wire into the angular opening until it touches on both sides and cannot go farther; the number stamped on the right of the slot at the point of contact indicates the gauge of the wire according to the American Standard screw gauge. The back of the gauge is graduated B.W.G. on the right side, and B. & S.W.G. on the left side.

**Precautions against Damaging Work in Progress.**—The principal causes of damaged work are incautious blows, producing indentations or fracture; excessive pressure, which may distort or fracture the work, or produce indentations; and careless use of tools, which either break or distort the work, or ruin it by reason of the removal of too much metal.

Blows from a hammer, directly or through the medium of a chisel, must always be carefully watched, particularly when dealing with cast-iron, or when chipping along a weak part or near an edge. Careless riveting may fracture a piece of work, or deform it slightly; so may the act of driving in a pin or other part with the main portion of the work improperly supported against the blows. An effort to straighten or to bend any part by hammer blows is often attended with much risk, unless the hammer is perfectly under control and the blows are accurately directed and the work correctly supported. In very cold weather iron or steel parts cannot be safely hammered unless they have been warmed slightly before trying to straighten or to bend them. The indentations produced on work by the pane of a steel hammer are often visible; but these

are quite unnecessary and may be avoided by using a brass or copper hammer, or by interposing a block of wood, or copper, or brass between the hammer and the face being struck.

Excessive pressure is produced by careless holding in the bench vice, and also by undue tightening of nuts or other fastenings. In the former case, the result may be a fracture, if cast-iron is in question, and more or less distortion if other metals or alloys are being dealt with. The mere indentation of the hard steel jaws of the vice is easily preventable by the use of soft clams; but the subtle effects of an extra squeeze are not so easily guarded against and much work may be thrown away after all through incaution in this regard. A point that reduces the risk of fracture of brittle parts is to have good rounding corners in the angles, instead of filing them out squarely; the latter procedure invites fracture, and weakens a piece to a surprising degree. Work with thin walls, including brass and copper tubes, requires the exercise of considerable caution to preserve their shape intact; the pressure of a vice, or of tongs, or the effect of careless bending is soon noticeable.

Careless tightening of nuts and screws may fracture lugs, or burst them, or twist the screws off, or strip the threads. And the slovenly application of a spanner or a screwdriver soon spoils the heads, pulling off the corners, and tearing up the heads in an unsightly fashion. For this reason it is sometimes advisable to insert temporary screws while fitting and testing, and replace these with new ones after everything is completed.

The careless use of tools may have one of three results. The work surfaces may be rendered unsightly by scratches, or irregularities where planes should exist; too much may be removed by injudicious application; the work may be cracked or twisted off by excessive pressure, or attempting to cut too deeply. The presence of scratches cannot be excused, and if they are present it shows that the workman has tried to finish the surface at too early a stage, or alternatively that he has cut too deeply, and left insufficient metal to complete the surface finish. Irregularities in regard to filing or to polishing show up badly in certain positions, and should be put right by a more skilful handling of the tools. Emery cloth held in the hand and not controlled by a backing stick will hardly ever produce good surfaces, and the smaller the area the more marked will the faults appear. Damage is often inflicted in a thoughtless moment through applying too much force when tapping or screwing, with the result that the work is burst, or that the rod twists off. If this happens with a screw-plate or a solid die, there is then the further trouble of having to remove the broken piece.

The breakage of tools, though it may not affect the accuracy or appearance of the work, causes much waste of time and expense. A broken tap or drill may cost considerable time in removal, while the delay caused by this, or by the breakage of a file or saw, is always annoying when there are no spares available.

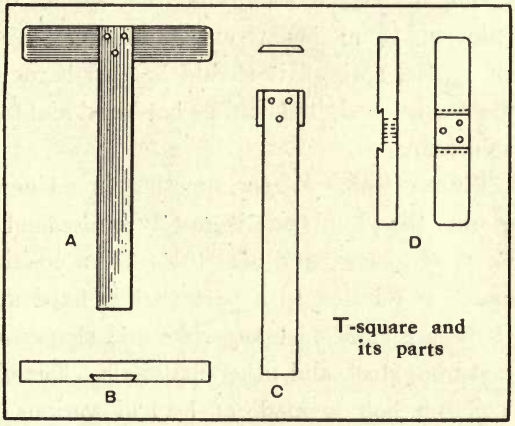
Several reasons are responsible for broken drills, such as excessive feeding, or the presence of a blow-hole in a casting, which catches the point and snaps it off, or a

twist-drill running through a hole too quickly, or the fact that the drill is not held in line with the hole and so bends to the snapping point. The choking which occurs when drilling brass or gunmetal is sometimes responsible for drill breakages, on account of the binding action of the cuttings in the hole, which press together until they jam the point and prevent it from rotating.

Files and hack-saws are broken through carelessness in applying too much pressure, or permitting the tools to wander sidewise, and so snapping them off. Lesser troubles in the way of teeth breaking in either of these tools is traceable to the fact that pressure is wrongly given on the backward stroke, or that the teeth are allowed to catch heavily on the starting edge when dealing with narrow pieces. Using a new file or saw on hard iron or steel will also snap the points of the teeth off in dozens, though the same accident would not follow if the file were used when slightly dulled.

**T-square.**—The T-square shown at A and B can easily be made from a piece of bar steel and a piece of sheet steel. A piece of bar material 2 in. long, $\frac{3}{8}$ in. thick, and $\frac{1}{4}$ in. wide is first carefully filed up square, and a slot made in it as shown at C, for the reception of the blade D. The blade can be made from a piece cut from an old wood saw blade after softening. At one end of the blade a dovetailed piece is formed, and this should tightly fit the slot in the top piece. Three $\frac{1}{16}$-in. holes are drilled through the blade and the head of the tool, and the edges of the holes countersunk for riveting. If the riveting is carefully done it should be impossible to notice the position of the

rivets after the tool is polished up. A slight allowance should be made on the edges of the blade before finally fixing it in the head, so that the tool can correctly be adjusted after riveting the two parts together. The T-square can be tested by means of another one, or it can be tried for accuracy in the following manner: The square should be laid on the edge of a metal block, or on the edge of a lathe bed, and a scriber line made along the edges of the



T-square and its parts

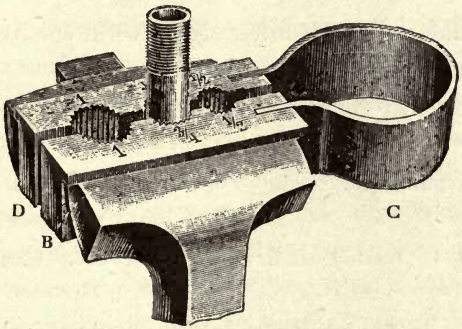
blade while the head is firmly held against the block or the edge of the lathe bed. Now, if the lines marked on the block, or on the bed, are parallel with the edges of the blade when the tool is turned over, the tool is correct. A tool of this description will often be found very useful when marking out small accurate work.

**Holding Pipe in the Vice.** — When a piece of pipe requires screwing, great difficulty is often experienced in holding it in the vice, for, if too much pressure is applied, the pipe will collapse. Apart from this, the fact remains

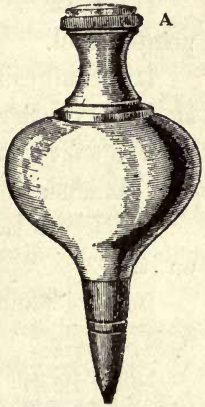
that very little surface of the vice jaws actually touches the pipe owing to its circular shape. A very handy device is illustrated at A, and it consists of two pieces of steel D and B and a spring C. The pieces D and B can be made from one piece of mild steel or cast steel, which is first drilled with three or more holes, and then sawn in half lengthwise. Grooves are then made in the faces of the holes to form teeth for gripping. Saw nicks are made at the end of the blocks, and the spring C fitted. If the device is made of cut mild steel (with the exception of the spring), it should be case-hardened. If it is made of cast steel, it should be hardened and tempered to a blue colour.

**The Plumb Bob.**—When erecting machinery, line shafting, etc., the plumb bob is greatly in demand for obtaining a vertical line, and also to test the position of a certain part in relation to a part that is fixed above it. Plumb bobs are made in many sizes and shapes, of lead, brass, cast-iron, steel, and other materials. The old form of oval plumb bob is made of lead of various weights from 8 oz. to 3 lb. One disadvantage of this type is that it gets badly knocked about in use. A good form of plumb bob B is made of brass, and is fitted with a hardened steel point. The cap A, which is knurled in order to facilitate unscrewing, has a small hollow inside, and a hole drilled in the top for the line or string to pass through. A neat and efficient plumb bob is turned and bored out of a steel bar, and knurled on the outside. Its hollow body is filled with mercury, and this gives a low centre of gravity, which naturally makes the bob very steady,

its weight being largely at the lower or pointed end. This type of bob is particularly useful in draughty positions, as, being heavy and slender, it is not so easily disturbed by a draught.




A.—Method of holding pipe in vice




B.—Steel-pointed plumb bob

**Some "Dont's" for the Inexperienced.**—Don't use a lathe bed as an anvil; accuracy cannot be expected after such treatment.

Don't calliper a piece of work when it is running.

Don't grind a right-hand tool to make it do the work of a left-hand tool.

Don't make double lines when marking out die work.

Don't use the same file for copper, lead, steel, iron, etc.; endeavour to keep a file for each material.

Don't think your tool kit is complete without an oil-stone.

Don't make tight and loose pulleys the same diameter.

Don't forget that you can file an emery wheel by means of a common file.

Don't try to file a hardened mandrel; this treatment destroys its accuracy.

Don't use a soft oilstone to put an edge on a sharp-pointed tool.

Don't fail to take out the drill frequently when cutting at a good depth and remove all the chips.

Don't hit a hardened die or any hardened work with a steel hammer.

Don't use a micrometer on work that has scale on it.

Don't attempt to feed a drill at a faster rate than it is cutting.

Don't forget to supply plenty of lubricant when drilling long holes.

Don't use a 3-ft. pipe to increase the leverage of a 1-ft. screw spanner.

Don't attempt to use a drill unless it is running perfectly true.

Don't use lard oil when cutting cast-iron threads; paraffin is better.

Don't try to force a screw into a hole when it is not properly fitted.

Don't use a lathe bed as a rack for storing turning tools.

Don't take a heavy chip when finishing screw threads in the lathe.

Don't use a spanner to tighten a nut unless the spanner is a good fit.

Don't use a hardened-steel hammer for driving mandrels out of or into work.

Don't use a tool with a broad nose when finishing small steel parts.

**Machining 4·5-in. High-explosive Shells.**—The shell blank is a piece of mild steel shaped by being heated and repeatedly struck between power dies until it assumes the form of a cylinder, of which one end is closed and the other open. The die-forged shell is allowed to cool quite slowly. In the case of a 4·5 in. high-explosive shell, the machining operations may be on the lines of the following, which describes the sequence of operations in a Canadian shop working on British munitions, but every shop will have its own individual methods, these being governed very largely by the machine equipment possessed. Details of the numerous inspections will not be given, but the reader will be prepared for the statement that the work has to be done within very narrow limits, that every stage in the production of the shell is elaborately supervised to ensure high quality of material and workmanship, and that any shells that fall short of the standard by ever so little are rejected. For many of the facts on pp. 133 to 139, relating to 4·5 in. shells, although not for the manner in which they are presented, the Editor of this handbook is indebted to a number of articles appearing in the "American Machinist."

The forged shell is held on an expanding mandrel in a heavy turret lathe, and its outside turned roughly to shape, this work comprehending a number of sub-operations, which, however, are successive, the work

remaining in the lathe all the time. First, the base of the shell is faced perfectly square and the sides rough-turned, except at the base end, where they are finish-turned in readiness for cutting the grooves for the copper banding. The recess for the base plug is rough-turned and finished in two operations, and the walls of this recess are undercut for the screw-threading, this work being done with a flat, circular, grooved cutter held in the turret; the waved grooves for the copper banding are rough turned, the work being held by its base end in a cup centre carried by the turret.

Again the cup centre is brought into use, and the waving and the undercutting of the grooving for the copper banding are accomplished; the waving of the groove assists the copper bands in making a gas-tight contact with the bore of the gun, and also, with the undercutting of the sides of the waved groove, helps to hold the copper banding more securely than a plain groove could possibly do.

The interior of the shell is still rough from the forging, and has now to be bored by tool after tool until the correct dimensions and degree of finish are attained. For this work a much heavier lathe than that used for the preceding set of operations will be necessary, and the shell will be held by a massive chuck in which it all but disappears. The tools that accomplish the boring are carried on a revolving capstan or turret as before, and are brought into play one after another.

Some shell-turning lathes have double spindles, so that two shells can be held at a time, the tools in the turret being so placed that while sub-operation No. 2 is taking

place on one shell, another shell is undergoing sub-operation No. 1.

For the rough-boring of the shell, there may be used a four-fluted reamer-like cutter, which is hollow for the passage of lubricant; as fast as the metal is cut away, the lubricant washes it out of the bore along the flutes. The first cutter roughly bores the straight part of the shell, and the next one roughly bores the domed part, but as it works into the shell another cutter, carried at the side of the same arbor nearer the turret face, comes into operation —a wide flat one that reamers the mouth of the shell. Two other cutters applied in succession finish the bore, and face up the open end of the shell.

By means of heavy dies operated by a steam hammer or hydraulic press, the shells are now nosed—that is, their open ends are drawn in to a taper. Those ends are heated in a gas or oil furnace, the shells conveyed rapidly to the anvil of the hammer or press and placed in fixed dies, the top die then descending once or twice and squeezing the end into taper form. The shell is immediately placed nose down in ashes so as to retard the cooling and thereby anneal the steel.

Consequent upon the nosing of the shell, part of the interior has now to be re-bored, and the mouth re-faced. In boring the inside of the nose to profile, the movement of the boring bar to effect the desired shape is automatically controlled by an arrangement which obliges the tool to follow the outline of a slot cut in a former plate. Next the shell is placed on the horizontal table of a drill press, where it is held by a heavy holder or clamp, and a screw-tap

then descends and taps a thread in the nose of the shell. Probably in many factories this tapping is done in the lathe. For the finish-turning of the outside of the shell, it is mounted between centres in a lathe which may be of a lighter type than those used for the boring. Special attachments are necessary, these consisting (1) of a female centre supported in the tailstock to receive the base of the shell, and (2) of a screw plug which enters the nose and is fitted with a dog driven from the face-plate. The turning is almost wholly automatic, the shape being controlled by a former in the manner already indicated.

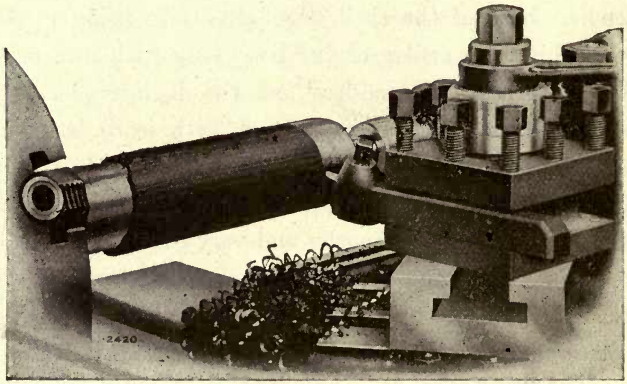
The shell now undergoes close inspection, gauging and weighing, and should it happen to be an ounce or two over the allowance it will need to be again profile-bored.

For the purpose of screwing in a base plug, the recess in the base of the shell is now screw-threaded left-handed, the work being done in the lathe. The purpose of the base plug is to obviate the possibility of the explosive charge in the shell being ignited when the gun is fired. There is always a possibility of "pipes" or flaws in the base of the shell, and these might form a means of communication between the charge in the cartridge, and that in the shell itself. Were a high-explosive shell to burst in the gun it would involve fearful destruction to everything and everybody round about. By providing a base plug, which is a simple piece of automatic or semi-automatic turning, the possibility referred to is obviated. There might, of course, be tiny flaws in the base plug, but by arranging that the grain of the steel runs at right angles to the length of the shell, it is impossible for these,

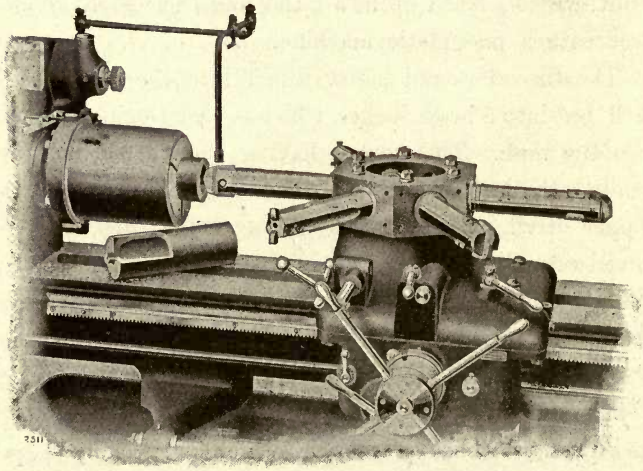
should they exist, to coincide with any in the shell. These base plugs are not inserted until after the shells have been washed in hot soda-water and sand-blasted inside and out. Elaborate care is taken to see that the base plug is a perfect fit, and that it screws right into contact with the base of the shell, the latter fact being proved by touching the centre of the base plug with iron oxide cement (never with red-lead, as the high explosive is liable to decomposition in contact with lead), screwing in the plug, unscrewing and observing whether the cement has been spread on the base of the shell. Next, the shell passes through a lengthy and very careful inspection, a certain percentage of the shells made is selected for test, and. if all goes well, the base plugs are finally screwed in, having first been coated, threads and all, with iron oxide cement. The base plugs are screwed home with a 6-ft. wrench, faced up in a lathe, and their edges riveted over with a pneumatic machine.

The fuse does not screw direct into the nose of the shell, but into a brass socket, which is very forcibly screwed into the nose. This socket having been fitted, but not finally attached, the shell is now ready to receive the copper driving bands which slip over the shell, and are forced into the wave grooves, where they are held by the undercutting already referred to; hydraulic presses may be used for forcing on the bands. The interior of the shell is now varnished with pure gum-copal varnish, which is baked on at 300° F. for eight hours, and the shells then pass to a heavy lathe in which a specially shaped tool turns the copper bands to the desired dimensions.

The shells are now painted, having first been washed with petrol to remove grease; two coats of leadless paint are given. Special machines are available for the purpose. Next, the brass socket is screwed in place, the threads having first been luted with a mixture of



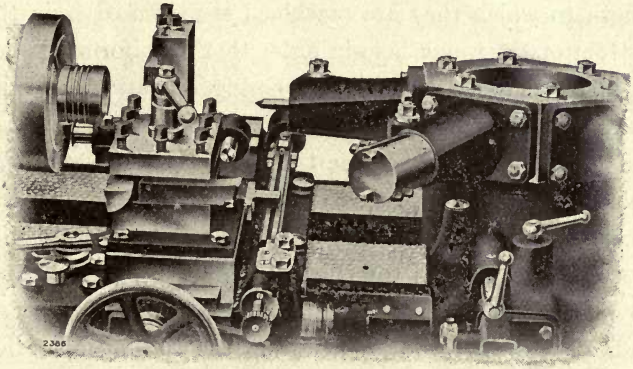
A.—Rough-turning 4·5 shell chucked on taper mandrel



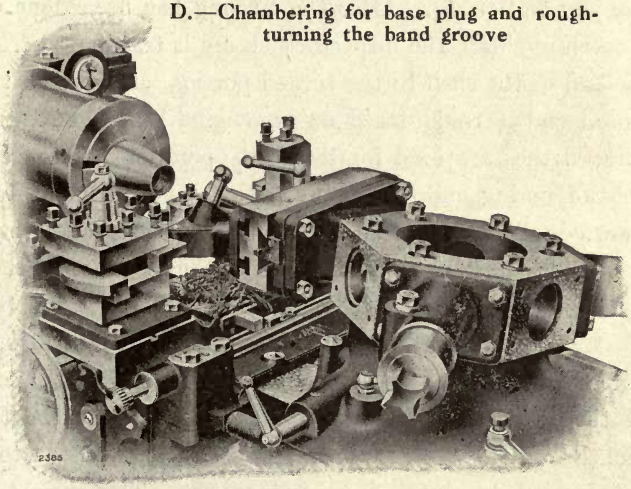
B.—Boring and bottoming 4·5 shell

whiting, vaseline, and castor oil; and, finally, the shells are weighed and boxed up for transport. The 4·5 high-explosive shells weigh 27 lb. 10 oz., and are rejected if they weigh more than plus 2 oz. or minus 4 oz.

ANOTHER SYSTEM.—The following sequence of opera-



D.—Chambering for base plug and rough-turning the band groove

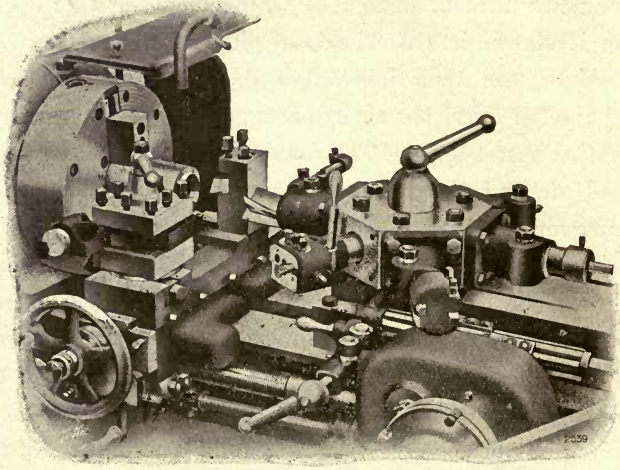


C.—Machining nose and mouth of 4·5 shell after closing-in or nosing

tions on a 4·5-shell is recommended by Alfred Herbert, Ltd.: The forgings are cut off to length, either on engine lathes or cutting-off machines, and about 1 in. is left at the open end to allow for the shortening that takes place during the subsequent closing-in or nosing operation. The length to which they are machined is measured from the bottom of the rough hole in order that a uniform amount of metal may be left for the boring operation on each shell. The forgings are now chucked on a mandrel, and rough-turned on the outside true with the bore, sufficient being left on the diameter to allow of a finishing cut later. The mandrel itself, in the simplest form, consists of a piece of steel held in the chuck and roughly turned taper to fit the rough forgings; the friction of the taper is sufficient to do the driving during the turning operation (*see* illustration A). After the turning has been done on a batch of shells, the inspector's stamp is transferred from the end of the shell to the turned portion, after which the closed end is rough-faced on an engine lathe. Hexagon turret lathes are used for the next operation, which consists of boring and bottoming. The tool arrangement is shown in B. The shells then proceed to a press, where the open ends are closed in, and the machining then continues, as follows: On combination turret lathes (*see* illustration C) the reduced hole in the nose is opened out, bored with single-point tools, and threaded; the nose of the shell is profile-turned, and the radius near the mouth formed. The shells have now to be adjusted to a definite weight, by facing off the base. This weight is the weight of the finished shell plus the allowance on the

outside diameter and the amount in the band groove. For the actual adjusting operation any type of engine lathe provided with a suitable chuck can be used. At the next operation the shells are held in a chuck on a combination turret lathe, and located from the base end of the shell. The chamber for the base plug is bored to depth and chased, and at the same setting the band groove is roughly formed. The tool arrangement for this operation is shown in D. The base plugs, made on separate machines, are then inserted, and, after being cemented and riveted over, the shells are again chucked on a combination turret lathe. The rough side of the base plug is faced off, and the waving of the band groove done. The arrangement of the former cam for the waving operation is similar to that described later for the 18-pounder shell. The method of using a double-sided cam is positive, and does not rely on weights or springs. The latter sometimes give trouble, if the cut is not put on very gently, for the tool digs in and rips out the rib, owing to the copy roller coming out of contact with the cam. The outside of the shell is finish-turned or ground to size, after which it is again weighed. If still on the heavy side, a little more metal may be removed from the inside of the shell, near the nose, a simple operation which can be done on any type of engine lathe. Although on the official drawing of this shell the fuse socket is shown as a separate piece, it is permissible to make it solid with the shell, and a number of firms are doing this. If, however, the fuse socket is made separately, it can be made from stampings or pieces cut off from the bar.

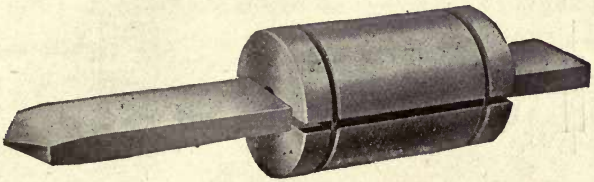
**Machining 18-pounder High-explosive Shells.**—When using the Herbert No. 4 capstan lathe for turning part of the outside diameter near the base and for boring and threading the chamber for the reinforcing plate, the necessary tool arrangement is as shown in A. The outside diameter is rough-turned with a tool on the back of the cross slide and the end roughly faced. A similar



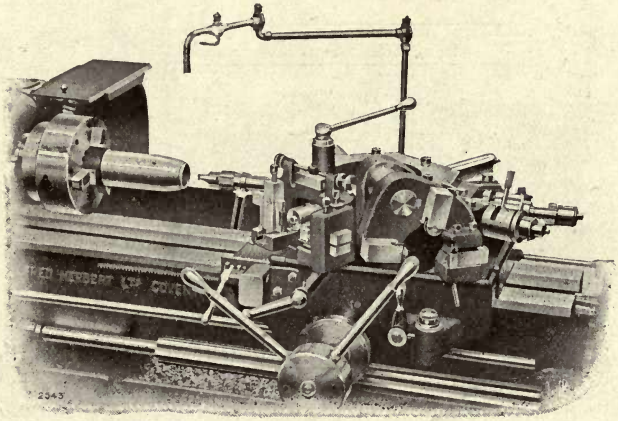
**A.—Turret lathe and tools for turning and boring 18-pounder high-explosive shell**

tool in the square turret does the corresponding finishing operation, while from the hexagon turret the end is successively centred, rough-bored with a four-flute reamer, recessed with a recessing tool slide, and finish-bored with single-point tools. From the square turret the bottom of the recess is traverse faced, and finally the thread is cut with a chasing mechanism. The time for this operation is twelve minutes. B shows the tool arrangement

on the No. 1 hexagon turret lathe, on which machine the shell is drilled, bottomed, finish-bored, recessed, and tapped, an operation performed in fourteen minutes. The shell body is next chucked in soft jaws in a 12-in. Coventry



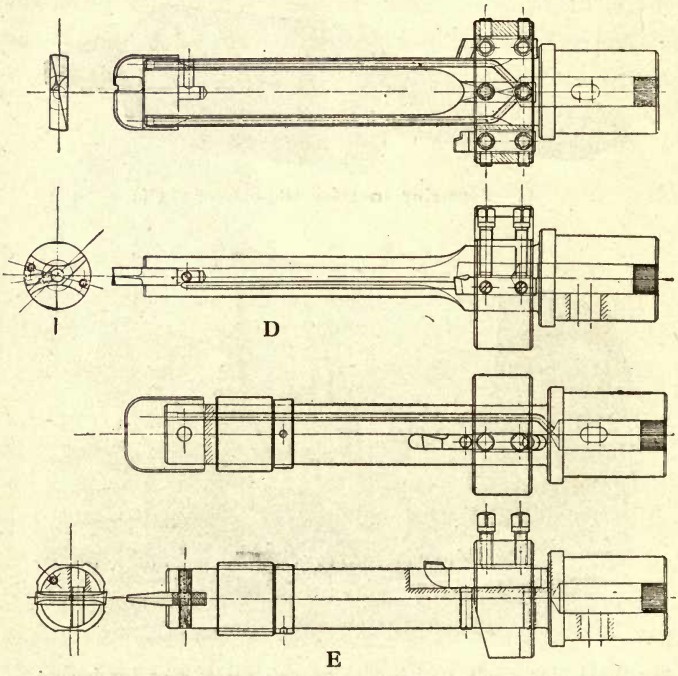
C.—Centring tool for 18-pounder shells



B.—Using triple tool holder on one turret face for boring 18-pounder shell

chuck. The first turret face carries a centring tool C for starting the drill true. This centring tool is a flat blade of high-speed steel clamped in a split bush. For the drilling is used a drill consisting of a mild-steel body with two straight flutes, carbonised all over, and hardened so as to prevent its " picking up " in the hole. The cutting edge

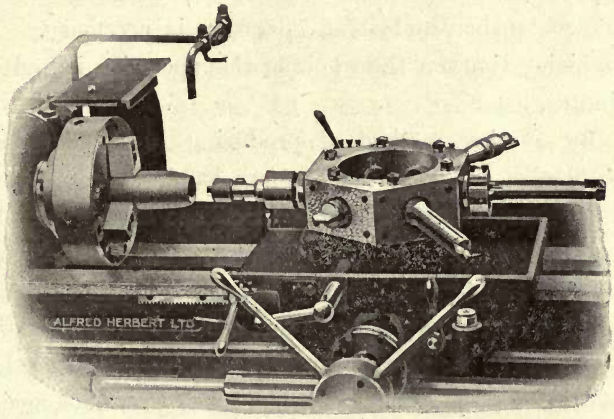
is of super high-speed steel fixed across the slot in the end of the body of the drill, and provided with spiral top rake exactly similar to that of a twist drill. Oil tubes are provided so as to take the oil under pressure up to the




**D and E.—Tools for boring 18-pounder shells**

point of the drill, the position of the oil tubes in the flutes being such that they are protected from the abrading action of the chips. This type of drill cuts an exceedingly smooth hole, and it is therefore possible to drill very close to finish size, the drills being actually 1·853 in. in diameter. At this operation a feed of nearly 2 in. per minute can be

regularly maintained. The bottom of the hole is next form-bored with the tool shown at D; this tool is made a few thousandths smaller in diameter than the drill, so that it only starts cutting when it reaches the bottom of the hole. A collar is clamped on the back end of the bar, and carries cutters for chamfering the nose of the shell and for coning the mouth. Oil tubes are fitted in this tool also. The finish boring is done with the tool illus-




F.—Boring 18-pounder shell on turret lathe

trated at E, which consists of a bar having a slot cut across the end, the bottom of which is slightly rounded; the cutter is a sliding fit in this slot, and is retained in position by a taper pin, the cutter having a clearance hole. The cutter therefore floats, and can be used with a feed as coarse as four cuts to the inch, producing a remarkably smooth hole. Behind the cutter is a revolving bush, which supports the bar when it is cutting at the bottom of the hole. A cutter clamped with a collar into a groove in

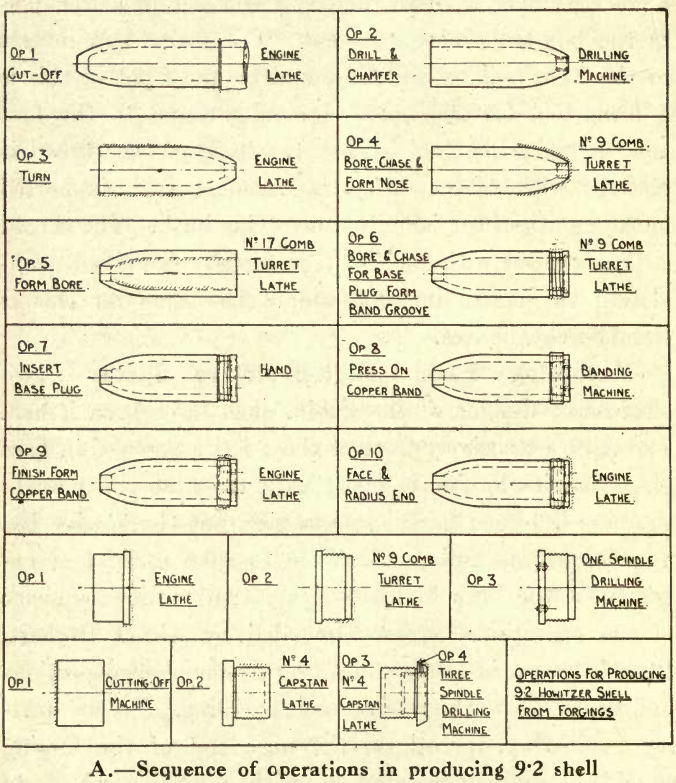
the bar provides for finishing the thread diameter. The recess is formed with a cutter in a standard recessing tool slide, and is identical with the one used on the No. 4 capstan lathe for the previous operation. The tapping is done with rough and finish taps. A revolving bush is fitted to the end of the tap bar; this pilots in the shell body and insures concentricity between the thread and the plain bore. The use of a tap of this description makes it possible to cut a thread accurately to gauge so that no subsequent hand-sizing operation is necessary. The machining time for the whole of this operation is fourteen minutes.

By another method of producing 18-pounder shells the blanks, cut from the bar, are handled on a Herbert No. 1 hexagon turret lathe, and at one setting the shell is drilled, bottomed, finish-bored, turned, nose-formed, recessed, and tapped. The use of a triple tool holder on one turret face enables eight tool stations to be used, the lay-out of the tools being shown in F. The blanks are held in a 9-in. three-jaw chuck, the blank being set back against the chuck face. In one hole of the triple tool holder is a centring tool, which starts the drill true. The second turret face carries a patent oil-supply drill, and the third a bottoming tool, all similar to those described in the preceding operation, except that the latter in this case has the collar with its chamfering and coning cutters omitted. This is followed by a finish boring tool, exactly as shown in E, but on the next turret face is a special form and cut-off slide carrying a revolving steady peg in the turret hole. With a cutter on the back of this slide the

end of the bar is formed down true with the hole. The turret is then rotated to the next face, to which is bolted a patent inverted roller steady box-tool. The turret hole on this face carries another revolving steady peg, in which a coning cutter is fitted, and this comes into action just as the box-tool finishes its cut. The turret now reverts to the form and cut-off slide, and on the front of this is a form tool for the nose. Indexing round to the first hole in the triple tool holder, the back of the thread is recessed with an eccentric-type recessing tool, supported in the mouth of the hole by a revolving bush. The thread is then tapped with the flat taps already described, completing the machining operation. The time for this is twenty-five minutes.

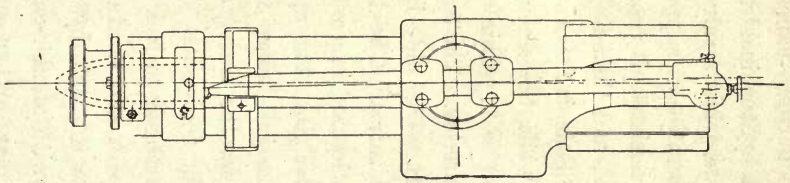
**Machining 9·2-in. High-explosive Shells.** — Two alternative designs of the 9·2-in. shell have been issued. The more extensively used of these has a screwed-in base plug, and its forging is made with the nose end closed: the bore is forged fairly close to size, but the outside has a generous machining allowance to take care of eccentricity of the bore in the forging. An outline sequence of the operations, as recommended by Alfred Herbert, Ltd., is shown in the line drawing A, the shaded portions indicating the work done at each handling. Before starting machining operations, the nose end of the forging should be roughly squared up with a fettling wheel, to present a fairly true surface for starting the drill, in operation No. 2. *Operation* 1.—The cutting off is done on a lathe fitted with a bell chuck, and a revolving steady in the tailstock for supporting the forging. In cutting off,

the position of the tool should be carefully measured from the inside of the forging, so as not to leave an excessive amount of metal for removing from the bottom end of the bore. *Operation* 2.—The forging is then chucked on

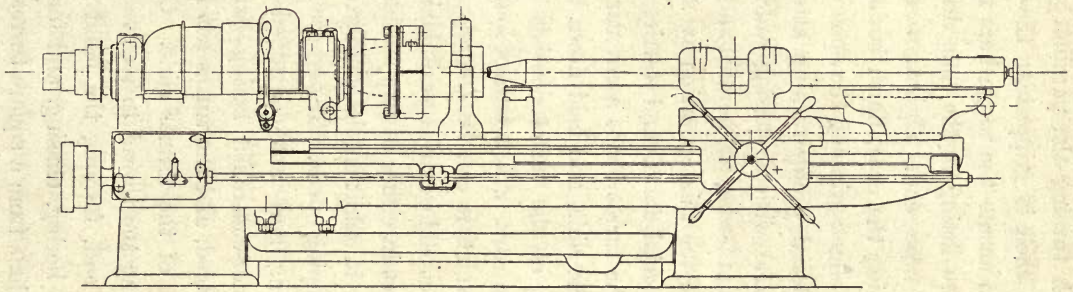



**A.—Sequence of operations in producing 9·2 shell**

a special fixture on a heavy vertical drilling machine; the fixture centralises the forging from the rough bore. A 2¼-in. hole is drilled through the nose, and the mouth of the hole coned. *Operation* 3.—This consists of rough and



B.—Turret lathe for boring 9·2 shells



finish turning the parallel part of the outside diameter. The shell is gripped at the open end by the inside, so as to ensure the rough bore running true, while a running centre fitting in the hole drilled at operation 2 supports the nose end. *Operation* 4.—This consists of profile-turning the nose, finish boring the nose, and threading, a bell chuck gripping the open end. The lathe is fitted with a special profile-turning attachment, while the screwing is done with a chasing saddle. *Operation* 5.—This consists of boring the parallel and profiled interior. The turret lathe for this operation is shown at B. The slide is of a special form, and carries a special turret. The base of the turret forms a circular turntable located in a recess in the slide, and held down by a circular gib. The upper part of the turret consists of two massive bosses with loose caps, which form a long support for the boring bar, in which it can be securely clamped by four nuts. The turret slide carries an indexing bolt arranged to lock the turret in either of two stations 180° apart, and the turret can, in addition, be solidly clamped to the slide by two clamping pads. These are for use with double-ended boring bars not controlled by a former. When using former-controlled boring bars, the indexing bolt is disengaged, and the turret left free to rotate under the influence of the former slide. *Operation* 6.—This consists of boring the thread to receive the base plug, counterboring the end, forming the band groove, and the waved ribs. The boring, chasing, and forming of the band groove are all done from a square turret, the waving being done from the back of the cross slide by a special slide operated by

a former-cam, which is attached to the shell itself. The shell is chucked as in operation 5. *Operation* 7.—This consists of screwing in and fixing the base plug. *Operation* 8.—The copper band is pressed on by any suitable type of press. *Operation* 9.—The forming of the band is done on engine lathes, the chucking being done by a screwed peg fitted in the nose of the shell, which is locked up by a coned lock nut. The base end may be supported by a dead centre in the base plug or else by running in a three-point steady on the outside diameter. The latter is probably the better method, as it ensures concentricity between the band and the body of the shell. Owing to the rather complicated form of the band, a number of tools is required, and these may be carried in a suitable holder, each tool being successively applied to the work, being positioned by suitable stops. *Operation* 10.—This consists of facing off the base plug in position, and forming the radius on the end. This is done on an engine lathe, the method of chucking being the same as at operation 9.

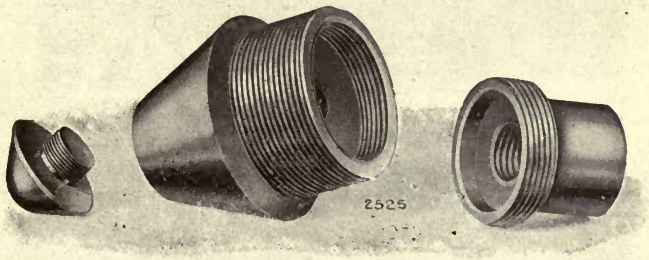
The Base Plug.—*Operation* 1.—The forging is held in a three-jaw chuck on an engine lathe, and the 7-in. diameter is turned, faced, and centred. *Operation* 2.—This is done on a simplified turret lathe. The threads are rapidly cut with a chasing saddle, separate rough and finish chasers being used. *Operation* 3.—This consists of drilling the two tommy holes, and is done on a drilling machine, the jig being of simple design.

The Nose Bush.—Although it is permissible to form the nose bush solid with the shell body, it is better practice, on a shell of this size, to make a separate nose bush,

as it enables a stronger boring bar to be used for operation 5 on the shell body. *Operation* 1.—The blanks are cut off to length. *Operation* 2.—This is done on a No. 4 capstan lathe, where the external thread diameter is turned and chased, the 1·9-in. hole drilled, bored, and coned. *Operation* 3.—This is done on the same lathe, the bush being held in a special chuck drawing back by the external thread. The 2-in. thread diameter is finish-bored, recessed, and chased, and the outside diameter is formed. *Operation* 4. —This consists in drilling the hole for the fixing screw.

**Machining Graze Fuses.** —The modern fuse is a complicated piece of mechanism. Illustration A shows the body, adapter bush, and cap of the graze fuse that is being used in conjunction with high-explosive shells. For making the body, material is used in the form of pieces previously cut off from gun-metal bar; alternatively stampings are being used, but these should be made with a parallel chucking portion to facilitate holding. At the first operation they are held, threaded end outwards, in a three-jaw hollow concentric chuck. The thread diameter is turned from the square turret, while the second tool forms the shoulder and the recess at the back of the thread. From the capstan they are centred, faced, and counterbored, whilst the succeeding tools drill the ·405 in. hole, ream it, and finish-bore and bottom the large thread diameter. The external thread is chased with an inverted chaser holder travelling away from the shoulder, and the large internal thread is finally recessed and tapped. The whole operation occupies 5½ minutes; the tooling is shown in B. At the second operation the fuse bodies are held on

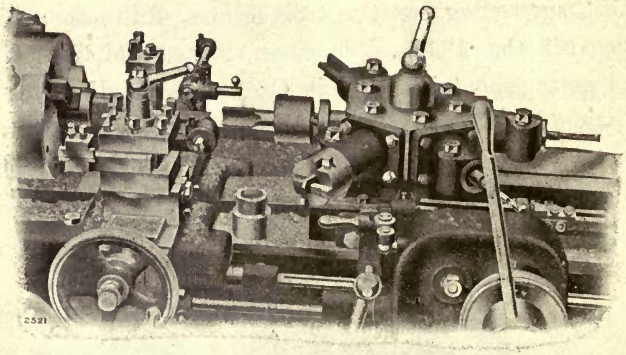
a screwed draw-back arbor peg, which pulls back against a fixed collar locating on the shoulder. The taper is formed with a broad forming tool on the back of the cross slide, whilst succeeding capstan tools centre, drill the ·54-in. hole, drill the ·195-in. hole, ream, recess, and tap. The tool arrangement is shown in C; the machining time is 3½ minutes. The adapter bush is made from 1 1/16-in. steel bar, which is gripped in a Coventry chuck, and set out to an adjustable stop. The plain diameter is turned with



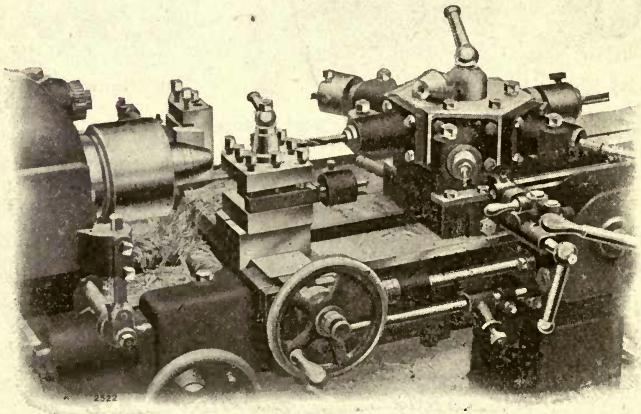

A.—Graze fuse cup, body and adapter bush for high-explosive shell

a roller-steady boxtool, after which the end is centred and faced, drilled, and bored, while from the square turret the thread diameter is turned, rough chased, and the piece finally cut off. The actual time for this operation is 7½ minutes. At the second operation it is gripped on the plain diameter by soft jaws in a three-jaw hollow chuck, and capstan tools successively counterbore, tap, and size the external thread, a spring sizing-die being used for this operation. The end is finish-faced from the cross slide. The total time for this operation is 2½ minutes. The cap is made from 1⅜-in. gun-metal bar, which is held

in a draw-in chuck. After being fed out to a stop, it is formed with two separate form tools in the square turret, and screwed. The rounding of the portion left by the



B.—Tool arrangement for first operation on graze fuse bodies



C.—Tool arrangement for second operation on graze fuse bodies

cut-off tool is subsequently finished on a shaving lathe, and the actual time for machining on a Herbert No. 4 capstan lathe is 1½ minutes.

# INDEX


ACCURACY, degrees of, 5
Alundum wheels, 97
Annealing, 99

BASE-PLUGS, shell 136, 137, 151
Black finish, 2
Boring in the lathe, 69-73
—— lathe, 41
—— shells, 135, 140, 143-145, 150
Brass-finishers' lathes, 41
Burnished finish, 3

CALLIPERS, 111-113
Capstan lathes, 41
Carborundum wheels, 97
Carriers, lathe, 42-44
Case-hardening, 4, 108-111
Centring lathe work, 47-50
Change gear calculations, 93-97
Chipping, 30, 31
Chisels, 30, 31
Chucking lathes, 41
Chucks, lathe, 44
Collars on bars and rods, 22-24
Corundum wheels, 97-99
Cut-meter, 57, 58
Cutting speed, 56-59, 63-65, 78-80
Cutting-off tool, 52

DAMAGING work, precautions against, 125-128, 131-133
Drawing-down iron, 16-20
Drilling, 62, 63
—— in lathe, 69-73
——, speeds for, 63
Drills, arboring, 66
——, bottoming, 67
——, breakage of, 127
——, flat, 59, 60
——, pin, 66
——, rose-head, 67
——, twist, 60-62, 64-66
Driving attachments, etc., 42

EMERY wheels, 97-99

FEED, 56-59
Filed finish, 2, 3
Files and filing, 31-34, 128
Finish, kinds of, 2-5
Fire, smith's, 16
Fits, 5
Foot lathes, 40
Forging high-speed steel, 29
—— iron, 16-25
—— tool steel, 27
Fuses, machining, 152-154

GAP lathes, 40
Gauges, block, 120
——: callipers, 111-113
——, Johanson, 120
——, limit, 119
——: micrometers, 113-118
——, plug, 119
——, ring, 119
——, screw-thread, 119
——, shell-thickness, 119
——, snap, 118, 119
——, step, 120
——, surface, or scribing-block, 47
——: Vernier micrometers, 116-118
——, wire, 121
Gear cutting, 82-84
Graze fuses, machining, 152-154
Grinding machines and lathe attachment, 97

HACK-SAWS, 12-14, 128
Hammers, 9, 125
Hardening and tempering steel, 4, 100-108
High-speed steel, 8, 9
—— ——, forging, 29
—— ——, heat-treatment of, 111

IRON, 5 6
——, annealing, 99
——, case-hardening, 108-111

JOHANSON gauges, 120

KNIFE tool, 48

LACQUERING, 4
Lathe, 37-42
—— chucks, 44, 45
——, double-spindle shell-turning, 134
—— driving attachments, carriers, etc., 42-44

Lathe faceplates, 44
—— lead or leading screws, 88
—— slide-rests, 45-47
—— work, centring, 47-50
—— ——: cutting speed, 56-59
—— ——: drilling and boring, 69-73
—— ——: feed, 56-59
—— —— on shells, 133-154
—— ——: surfacing, 55
—— ——: taper turning, 52-55
—— ——: tools, 50
—— ——: turning cylinders, 50-52
—— ——: use of stay, 55

MALLETS, 10
Micrometers, 113-118
——, Vernier, 116-118
Milling cutters, grinding, 80
—— ——, speeds for, 78-80
—— ——, various, 73-77
—— machines, 76-78

PAINTING, 4
Parting tool, 52
Pipe, holding, in vice, 129, 130
Planers, 81
Plating, 5
Plumb bob, 130
Polished finish, 3

REAMERS, 68, 69
Ring, length of iron for, 25-27
——, welding, 23

SAWS, 12-14
——, metal-slitting, 74
Scraped finish, 3
Scrapers and scraping, 34-36
Screw-cutting: calculating wheel trains, 93-97
—— in the lathe, 88-97
—— lathes, 41
—— by various means, 87, 88
Screw-threads, various, 84-86
Shapers, 81, 82
Shell, 4.5 high-explosive, 133
——, 9.2 high-explosive, 147-152
——, 18-pounder high-explosive, 142
—— base-plugs, 136, 137, 151
—— graze fuses, 152-154
Side-finishing tool, 48
Slide-rests, 45
Sliding lathes, 41
Slocombe drill, 48
Slotting machine, 82
Spanners, 15, 126
Spur-wheel cutting, 82-84
Stays, fixed and travelling, 55, 56
Steel, 7-9
——, annealing, 99
——, case-hardening, 108-111
——, forging, 27
——, hardening and tempering, 100-108
——, high-speed, 8, 9, 29
——, ——, heat-treatment of, 108
Surfacing, 55
Surfacing-lathes, 41

T-SQUARE, 128
Taper turning, 52-55
Tempering, 4, 104-108
Toolmakers' lathes, 42
Tool-steel, 7
——, forging, 27
Turning cylindrical work, 50-52
——, shell, 133-154
—— tapers, 52-55
Turret lathes, 41

UPSETTING or jumping-up iron 16-20

VERNIER, reading, 116-118
Vice, careless use of, 126
——, holding pipe in, 129

WELDING iron, 22-25
Wire gauges, 121-125
Wood-turners' lathes, 42

PRINTED BY CASSELL & COMPANY, LIMITED, LA BELLE SAUVAGE, LONDON, E.C
30.617

YB 52040

M277801

TJ1165
J75

THE UNIVERSITY OF CALIFORNIA LIBRARY